NEPRF Technical Report
3-76 (CSC)

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EXTENDED STUDIES OF A QUADRILATERALIZED SPHERICAL CUBE EARTH DATA BASE

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MAY 1976

Final Report

Prepared for

COMMANDER, NAVAL AIR SYSTEMS COMMAND
Department of the Navy
Washington, D.C 20361

NAVAL ENVIRONMENTAL PREDICTION RESEARCH FACILITY
Naval Postgraduate School
Monterey, California 93940

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (when data entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: NEPRF Technical Report 3-76 (CSC)

2. GOVT. ACCESSION NO.: TR-3-76

3. RECIPIENT'S CATALOG NUMBER: (CSC)

4. TITLE (and Subtitle): Extended Studies of a Quadrilateralized Spherical Cube Earth Data Base

5. TYPE OF REPORT & PERIOD COVERED: Final Report, July 1975—March 1976

6. PERFORMING ORG. REPORT NUMBER: CSC/TR-76/6008

7. AUTHOR(s): E. M. O'Neill, R. E. Laubscher

8. CONTRACT OR GRANT NUMBER(s): N00228-75-C-2329 NEW

9. PERFORMING ORGANIZATION NAME & ADDRESS: Computer Sciences Corporation, System Sciences Division, 8728 Colesville Rd., Silver Spring, Md. 20910

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: PE 35111N, CC54, WU055-6-1

11. CONTROLLING OFFICE NAME & ADDRESS: Naval Environmental Prediction Research Facility, Naval Postgraduate School, Monterey, California 93940

12. REPORT DATE: 27 May 1976

13. NUMBER OF PAGES: 114

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS. (of this report): Unclassified

15a. DECLASS./DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this report)

Approved for Public Release: Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in block 20, if different from report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (continue on reverse side if necessary and identify by block number)

Data Base, Map Projections, Constant Area Sensors, Meteorology, Satellite Data Processing

20. ABSTRACT (continue on reverse side if necessary and identify by block number)

This report describes the results of research into a number of aspects of a proposed global meteorological data base. Subjects covered include: improvement of formulation of map transformations; a rapid method of obtaining data base coordinates from satellite elements

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and scanner angles; comparison of two fast-filling algorithms, the maintenance of multiple- and variable resolution data bases; and the operation of maps in the data base coordinate system.

ABSTRACT

This report presents the results of a study of mathematical formulae and algorithms necessary for the implementation of the Quadrilateralized Spherical Cube Earth Data Base preprocessor function. Topics covered include an improved formulation of the inverse equal-area transformation, f^* ; the development of a new, exact, equal-area transformation utilizing a polar coordinate system on the cube face; an improved computation of the coefficients of the equal-area transformation, f , and its inverse, f^* ; a rapid method of obtaining cube face coordinates from Keplerian elements and scanner angle; a new fast-filling algorithm; and the maintenance of multiple and variable resolution data bases.

This report addresses the properties and merits of the newly derived transformation and compares it with a previously derived form. Approximation methods for the equal-area transformation are presented. A revised, fast-filling algorithm is presented, which combines the new method of cube face coordinate computation with a recently suggested pixel sampling scheme. Applications of these methods and algorithms to an initial operational preprocessor and to refined future programs are discussed.

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SECTION 1 - INTRODUCTION

Previous studies (References 1 and 2) have indicated that a quadrilateralized spherical cube dissection of the Earth will provide a uniquely simple and useful set of coordinates in which to store remote sensor data on a global scale. This representation divides the globe into six square grids, allowing an extremely simple and elegant addressing scheme.

A mapping function (Reference 1) has been developed which permits an equivalent (equal area) mapping of a sphere onto the faces of a cube. This mapping provides an ideal match to constant resolution sensors and allows the simplification of map factor calculations for meteorological applications. Figure 1-1 illustrates the cubic dissection of a sphere, and Figure 1-2 shows a map of the world as projected using the equivalent mapping function.

In studying the feasibility of implementing this quadrilateralized spherical cube Earth data base system, a number of areas were identified which were deemed worthy of further study. In the course of these studies, additional details and problems were brought to light. The initial objectives of this study were

- Improvement of the formulation of the data base mapping functions
- Study of methods of representing satellite motions in terms of the data base coordinate system
- Study of data base Input/Output optimization on the CYBER/175 computer
- Production of maps illustrating various geographic orientations of the data base cube

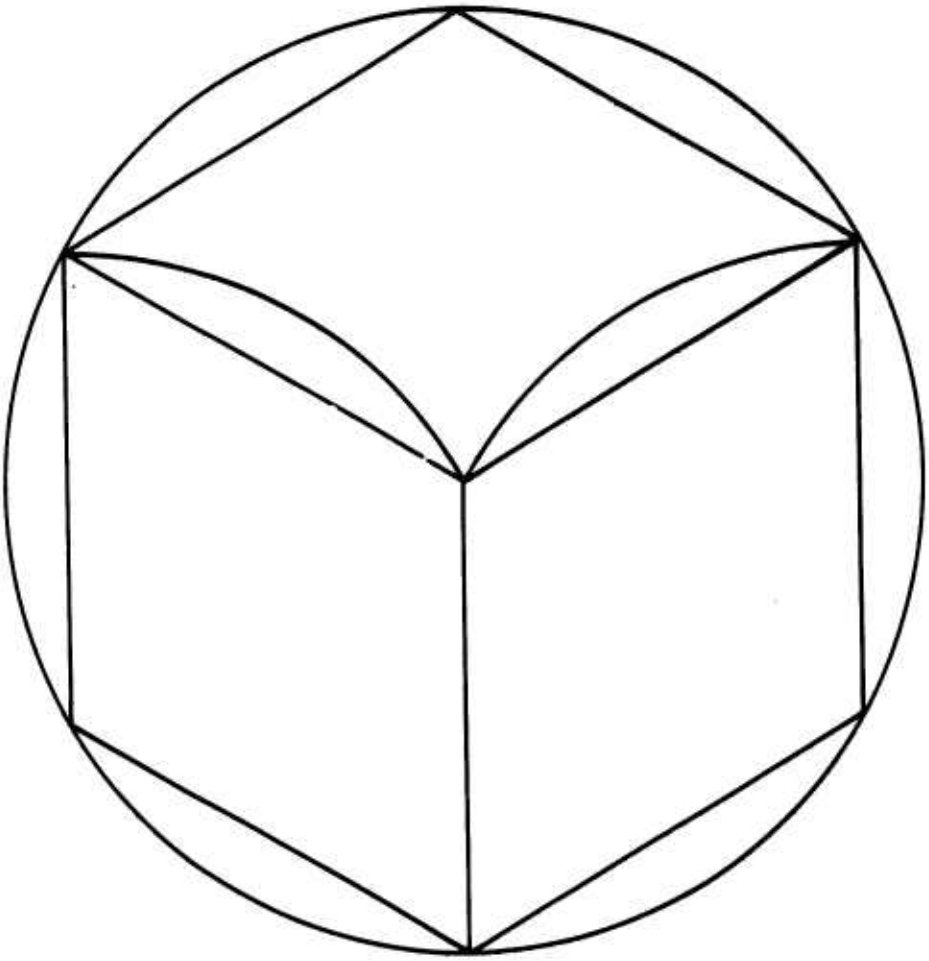


Figure 1-1. Cubic Dissection of a Sphere by an Inscribed Cube

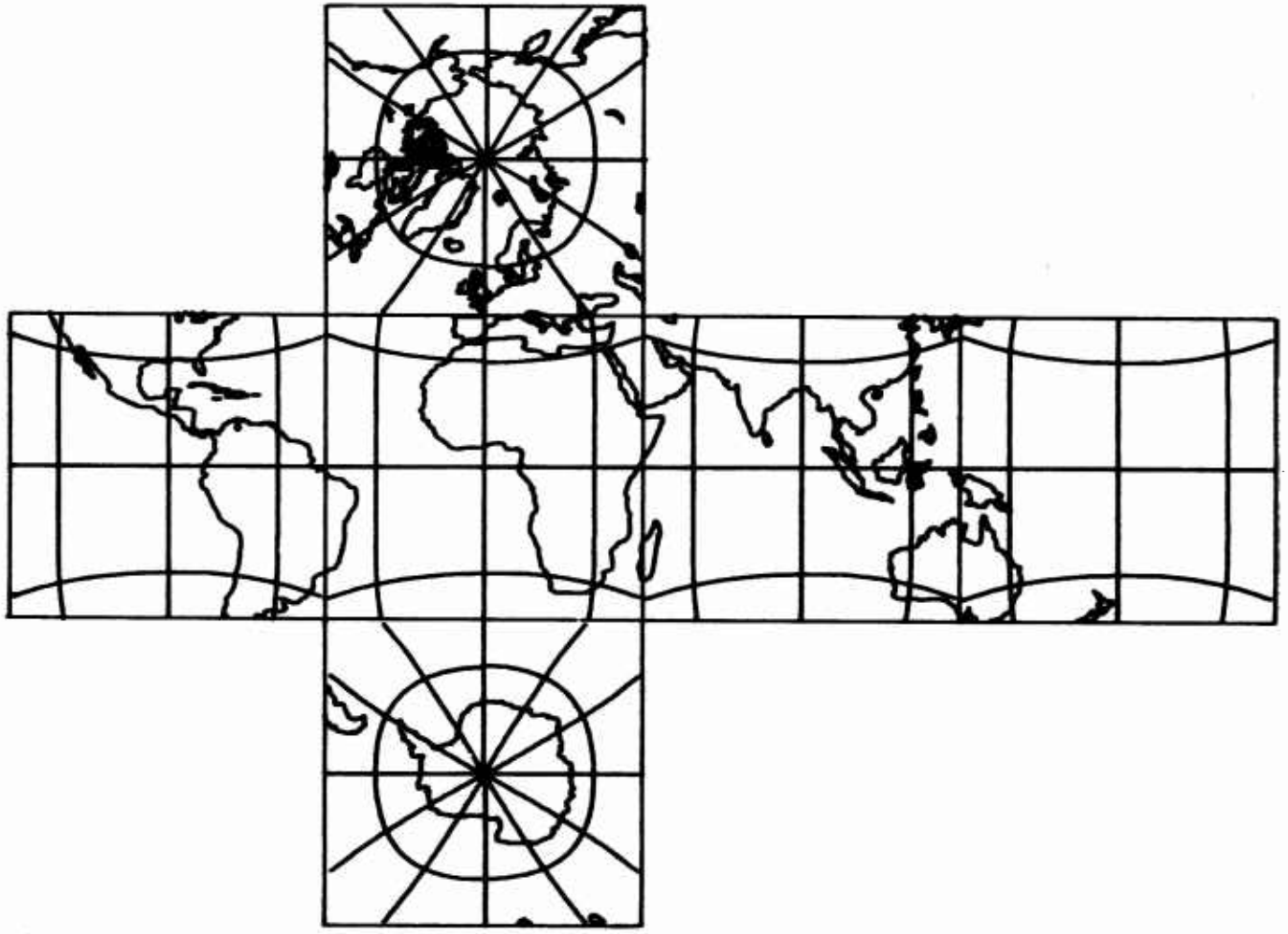


Figure 1-2. World Map on Equal-Area Cube

Additional studies required were

- Study of algorithms required to implement a revised data base filling scheme
- Improvement in the accuracy of the data base mapping functions and the matching of direct and inverse functions

The general purpose in these studies has been twofold: (1) to optimize the existing data base scheme and (2) to assist in the timely development of a preliminary implementation by improving and clarifying previously developed formulae and algorithms. Most sections of this report deal with the maintenance of current data in the data base. The portion of the system which will fulfill these functions has been designated the preprocessor program.

This report presents several new and refined algorithms and mappings aimed at improving the speed and accuracy of an operational preprocessor program.

SECTION 2 - BACKGROUND

2.1 PRIOR RESULTS

A proposed set of algorithms for implementing the quadrilateralized spherical cube data base was presented in another report (Reference 1). That report addressed numerous problems: mapping points from the Earth's surface into the data base, determining serial addresses for data base locations, fast-filling and data retrieval, and determining the ground locations of scanner pixels. The results presented herein are derived from further study of these problems. For background information, Sections 2.2 and 2.3 present the previously derived transformation and method of fast-filling.

2.2 PREVIOUSLY DEVELOPED TRANSFORMATION

Section 2 and Appendix A of Reference 1 present the mathematical development of the mapping function, f , and its inverse, f* . These functions relate the data base coordinates (x , y) to the rectangular coordinates (ξ , η) of the point on any cube face resulting from the central projection of a datum point on the sphere. For convenience, the mapping functions, f and f* , are repeated here. The coordinates (ξ , η) are related to the data base coordinates (x , y) via

$$\xi = f(x, y)$$
$$\eta = f(y, x) \qquad (2\text{-}1)$$

where the function f , called the direct function, is given by

$$f(x, y) = \gamma x + \frac{(1-\gamma)}{r_o^2} x^3$$

$$+ xy^2 \left(r_o^2 - x^2\right) \left[\delta + \left(r_o^2 - y^2\right) \sum_{\substack{i \geq 0 \\ j \geq 0}} c_{ij}\, x^{2i}\, y^{2j}\right] \qquad (2\text{-}2)$$

$$+ x^3 \left(r_o^2 - x^2\right) \left[\omega + \left(r_o^2 - x^2\right) \sum_{i \geq 0} d_i\, x^{2i}\right]$$

where

$$\delta = \frac{1}{4r_o^4} \left[-(\mu + 2\gamma) + \sqrt{(\mu^2 - 4\mu\gamma + 4\gamma^2 + 16\sqrt{2}\gamma^2)}\right] \qquad (2\text{-}3a)$$

$$= 0.79048\ 64491\ 208$$

$$\omega = \frac{1}{2r_o^4} \left(3 - 2\gamma - \mu - 2r_o^4\, \delta\right) = -1.2254\ 41487\ 984 \qquad (2\text{-}3b)$$

$$\gamma = \sqrt{\pi/6} \qquad (2\text{-}3c)$$

$$\mu = \sqrt{\frac{\sqrt{3}\,\pi}{2}} \qquad (2\text{-}3d)$$

$$r_o = 1/\sqrt{3} \qquad (2\text{-}3e)$$

and the coefficients c_{ij} and d_i are

$$c_{00} = -2.7217\ 05366\ 1814 \qquad d_o = 1.4833\ 12929\ 4187$$

$$c_{10} = -5.5842\ 16830\ 5430 \qquad d_1 = 1.1199\ 72606\ 9742$$

$$c_{01} = 2.1711\ 17480\ 9423 \qquad d_2 = 6.0515\ 38216\ 1464$$

$$c_{20} = -3.4578\ 62747\ 3390$$

$$c_{11} = -6.4160\ 15152\ 6783$$

$$c_{02} = 1.9736\ 26575\ 8872$$

The inverse function, f^*, relates (x, y) to (ξ, η); that is,

$$\begin{aligned} x &= f^*(\xi, \eta) \\ y &= f^*(\eta, \xi) \end{aligned} \tag{2-4}$$

and is given by

$$\begin{aligned} f^*(\xi, \eta) = \gamma^* \xi &+ \frac{(1-\gamma^*)}{r_o^2}\xi^3 \\ &+ \xi\eta^2\left(r_o^2 - \xi^2\right)\left[\delta^* + \delta_1^*\left(r_o^2 - \xi^2\right)\right. \\ &\left. + \left(r_o^2 - \eta^2\right)\sum_{\substack{i\geq 0 \\ j\geq 0}} c_{ij}^* \xi^{2i}\eta^{2j}\right] \\ &+ \xi^3\left(r_o^2 - \xi^2\right)\left[\omega^* + \left(r_o^2 - \xi^2\right)\sum_{i\geq 0} d_i^* \xi^{2i}\right] \end{aligned} \tag{2-5}$$

where

$$\gamma^* = 1/\gamma \tag{2-6a}$$

$$\mu^* = 1/\mu \tag{2-6b}$$

$$\gamma_1^* = 1/\left(\gamma + r_o^4\,\delta\right) \tag{2-6c}$$

$$\mu_1^* = 1/\left(\mu + 2r_o^4\,\delta\right) \tag{2-6d}$$

$$\delta^* = (\mu_1^* - \mu^*)/2r_o^4 \tag{2-6e}$$

$$\omega^* = \left(1/2r_o^4\right)\left(3 - 2\gamma^* - \mu^* - 2r_o^4\,\delta^*\right) \tag{2-6f}$$

$$\delta_1^* = \frac{1}{r_o^2}\left[\frac{(\gamma_1^* - \gamma^*)}{r_o^4} - \delta^*\right] \tag{2-6g}$$

and the coefficients c_{ij}^* and d_i^* are

$c_{00}^* = 3.973\ 89249$ $\qquad$ $d_0^* = 1.811\ 28250$

$c_{10}^* = 6.591\ 19476$ $\qquad$ $d_1^* = 37.635\ 47857$

$c_{01}^* = -25.368\ 92536$ $\qquad$ $d_2^* = 63.000\ 23655$

$c_{20}^* = -73.064\ 97000$

$c_{11}^* = 77.381\ 61133$

$c_{02}^* = 21.685\ 89623$

The use of f^* in an algorithm for obtaining the data base coordinates (x, y) of any datum point on the Earth's surface is described in Section 3.3. The algorithm presented in Section 3.3 is the result of the present study to obtain a method of implementing f^* in a computationally efficient manner.

2.3 PREVIOUSLY DEVELOPED FAST-FILLING ALGORITHM

Sections 4 and 5 of Reference 1 present a "fast-filling" method for updating the data base. The method was developed to obtain, as directly as possible, the data base location corresponding to the location of a given scanner data element and to store the value associated with that element in the calculated data base location. Starting with a given satellite location and scanner angle, a series of five steps are necessary to calculate the corresponding data base location.

1. Determine the three-dimensional Cartesian coordinates of the point observed by the scanner.
2. Determine the face onto which the point is to be mapped
3. Project from the Cartesian (a, b, c) system into an intermediate system (ξ, η) as shown in Figure 2-1
4. Transform from (ξ, η) into two-dimensional Cartesian coordinates (x, y) on the face of the data base cube
5. Convert from face number and (x, y) to a serial location in the data base

This transformation need not be performed for every point, since both the projection onto the Earth's surface and the (ξ, η) to (x, y) transformation may be linearly approximated over a relatively long range. Thus, the complete computation is required only for widely spaced benchmark points, with intermediate points being determined by interpolation.

Input and output are handled, as described in Section 5 of Reference 1, by blocking both the input data and the data base into rectangular arrays. Methods for handling problems such as queuing data base I/O, splitting input blocks across face boundaries, and locating a vertex within an input block were also discussed in Reference 1.

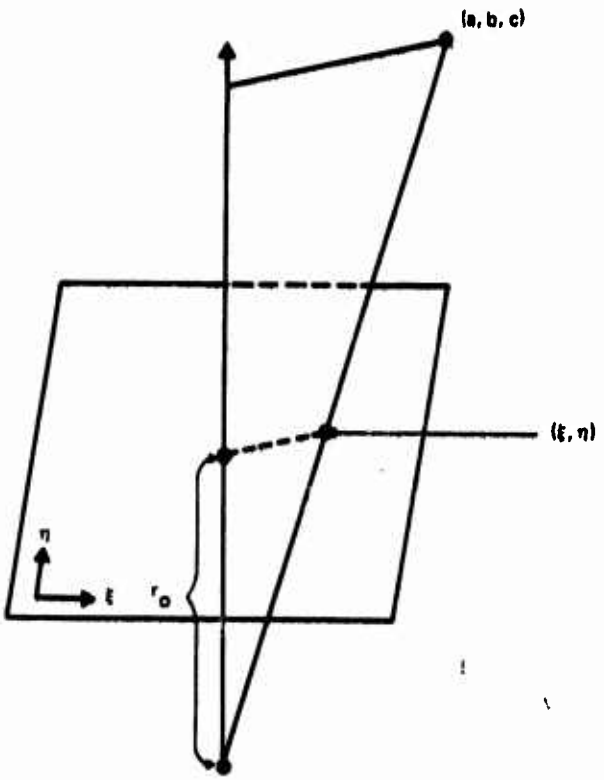


Figure 2-1. Projection From the Cartesian (a, b, c) System onto the Intermediate (ξ, η) System

In Reference 3, this scheme was compared with an alternative scheme. The alternative scheme follows the above method through step 3; then, instead of storing from the input block directly into the data base, the following steps are performed:

- For each input data block, determine which data base blocks will be completely covered by the input data
- Determine, in the (ξ, η) system, a set of benchmark points corresponding to the corners of the data base blocks to be filled
- Use the above benchmarks to interpolate the (ξ, η) coordinates corresponding to each (x, y) data base location and store the closest point in the input data block into the corresponding serial location

This method offers the advantage of providing a completely filled data base block and eliminates data base read accesses during the update process. After a thorough examination of this method, CSC concluded that the advantages outweigh the slight additional computational cost incurred in finding the appropriate data base blocks. Consequently, some of the work of this report was oriented toward this approach.

SECTION 3 - NEW PROJECTION AND TRANSFORMATION METHODS

3.1 GROUND TRACE EQUATIONS IN KEPLERIAN ELEMENTS

This section presents general relations that yield the geocentric coordinates of the subsatellite point and of any point on the Earth's (spherical) surface lying on an arc scanned by an onboard satellite sensor. These geocentric coordinates are to be computed as an intermediate step in algorithms for computing data base coordinates (Sections 3.2 and 3.3).

The following subsections distinguish between two cases: (a) the computation of the coordinates of the subsatellite point, and (b) the computation of the coordinates of any point on the scan arc. Although the first case could be treated as a special case of the second, its development is separated in order to facilitate computer implementation. The following subsections summarize the results, which are developed in detail in Appendix A.

3.1.1 Subsatellite Point

It is assumed that the satellite ephemeris is available in the form of Keplerian orbital elements. Expressions can be obtained in terms of these elements for the Earth-centered direction cosines (l, m, n) of the subsatellite point in the equatorial x, y, z coordinate system shown in Figure 3-1.

Since the subsatellite point lies on the geocentric position vector of the satellite (see Figure 3-1), l, m, and n will be identical with the corresponding direction cosines for the satellite's orbital position. The desired expressions for l, m, and n are developed in Appendix A to be

$$\begin{aligned} l &= +\cos\Omega\cos(\omega+f) - \sin\Omega\sin(\omega+f)\cos i \\ m &= +\sin\Omega\cos(\omega+f) + \cos\Omega\sin(\omega+f)\cos i \\ n &= +\sin(\omega+f)\sin i \end{aligned} \qquad (3\text{-}1)$$

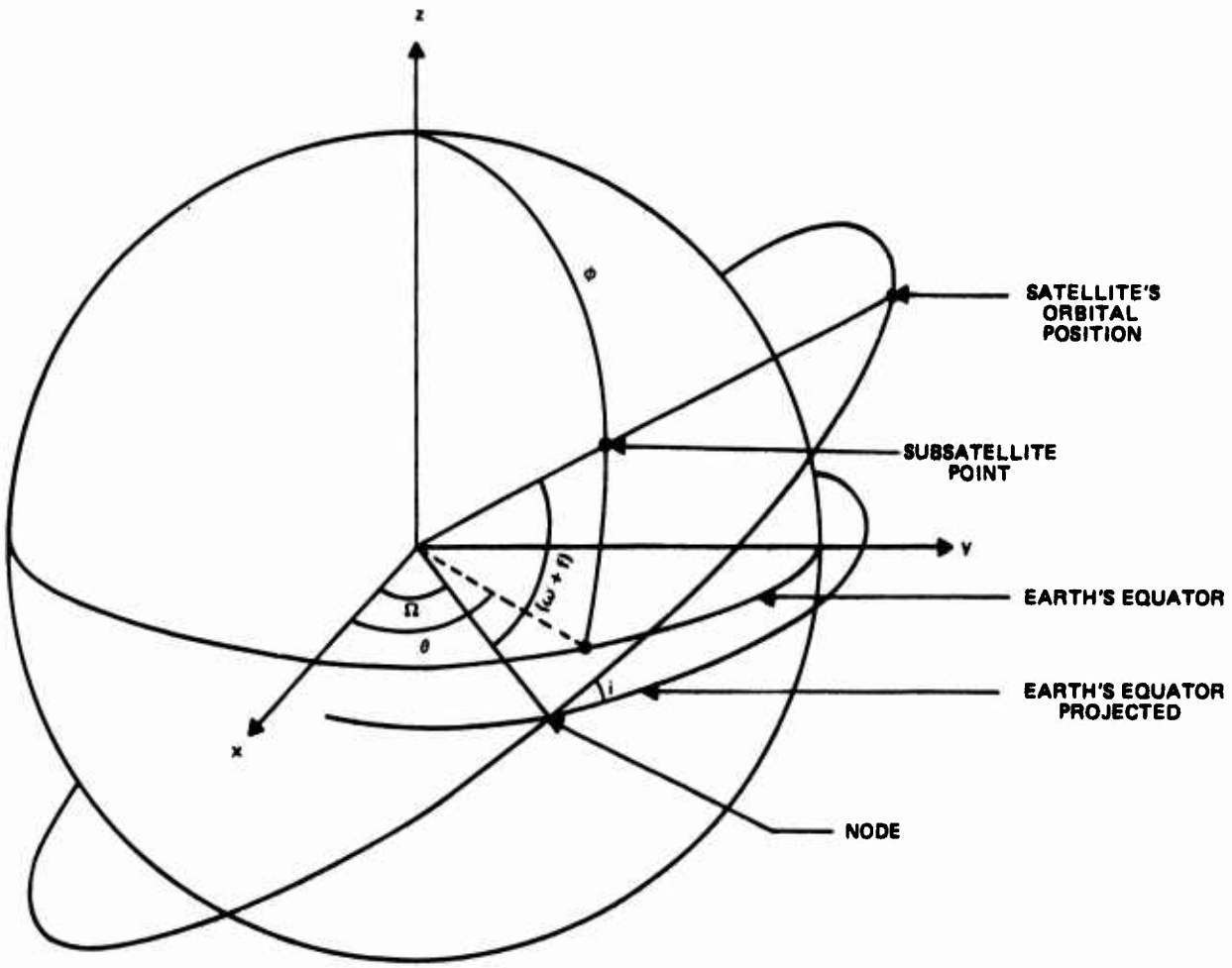


Figure 3-1. Keplerian Orbital Elements and Geographic Coordinates

The angular arguments are Keplerian elements and are referenced to the true equator and prime (Greenwich) meridian of date coordinate system. The direction cosines (l , m , n) in Equation (3-1) are obtained for the subsatellite point corresponding to any point in the orbit using the true anomaly, f , which reflects the motion of the satellite in its orbit, and the time-dependent node, Ω , which reflects the rotation of the Earth. The time dependence of the node is given by

$$\Omega = \Omega_o - s \qquad (3\text{-}2)$$

where Ω_o is the initial (constant) value of Ω and s is the elapsed Greenwich sidereal time since the instant that $\Omega = \Omega_o$. For high precision, Ω , ω , i , and s should be corrected for the Earth's nutation, precession, and polar motion.

3.1.2 Nonzero Scan Angle

It is assumed that the satellite collects data through an onboard sensor which scans the surface of the Earth through an arc of fixed size in such a way that its sweep carries it through the subsatellite point in a direction at right angles to the direction of the satellite's orbital motion. The trace of the scan arc on the surface of the (spherical) Earth is a segment of a great circle subtending a fixed central angle, ψ_o , as illustrated in Figure 3-2. The introduction of the central angle, ψ_o , though generally applicable in defining the ground location of a scan element (datum point), is particularly suitable when scan elements are spaced equally along the great circle arc.

Expressions are presented below for obtaining the geocentric longitude, θ' , and colatitude, ϕ' , of any pair of points (datum points) on the scan arc which are located symmetrically with respect to the subsatellite point. Details of their development are given in Appendix A. These expressions are then

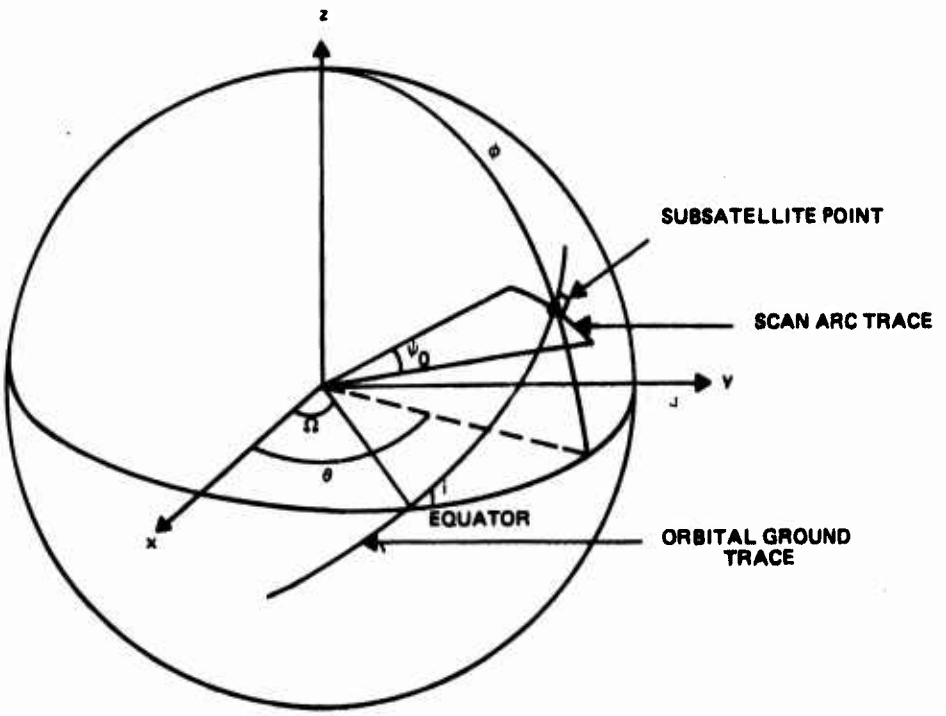


Figure 3-2. The Scan Arc as a Central Angle

employed in Sections 3.2 and 3.3 in describing the two alternative algorithms for obtaining the data base coordinates (x, y) of the datum points.

First, the sines and cosines of the geocentric longitude, θ, and colatitude, ϕ, of the subsatellite point are required in terms of the direction cosines available from Equation (3-1), i.e.,

$$\sin \phi \cos \theta = l \tag{3-3a}$$

$$\sin \phi \sin \theta = m \tag{3-3b}$$

$$\cos \phi = n \tag{3-3c}$$

Actually, Equation (3-3c) yields both $\cos \phi$ and $\sin \phi$, since $0 \leq \phi \leq 180$ degrees. Consequently, $\sin \theta$ and $\cos \theta$ can be determined from Equations (3-3a) and (3-3b).

Returning to the scan arc, it is convenient to view $\psi/2$ as a general variable describing the positions of any pair of points along the arc. The following expressions yield two unique values for both θ' and ϕ', depending on the algebraic sign of $\psi/2$. Thus,

$$\cos \phi' = \cos \phi \cos \psi/2 - \cos i \sin \psi/2 \tag{3-4}$$

where $\cos \phi$ and $\cos i$ are already available. Equation (3-4) gives ϕ' uniquely, since $0 \leq \phi' \leq 180$ degrees, from which $\sin \phi'$ is then computed and used in

$$\sin (\theta' - \theta) = \frac{\cos (\omega + f) \sin i \sin \psi/2}{\sin \phi \sin \phi'} \tag{3-5}$$

$$\cos(\theta' - \theta) = \frac{\cos \psi/2 - \cos \phi \cos \phi'}{\sin \phi \sin \phi'} \qquad (3\text{-}6)$$

to obtain θ', where all of the terms to the right of the equalities have previously been determined.

Caution is necessary when applying Equations (3-5) and (3-6) near the poles, since these relations are singular for subsatellite points or datum points near the poles. This is expected, since the geocentric longitudes θ and θ' are undefined at the poles. No problem need arise in computations, however, since the satellites are not expected to have exactly 90-degree inclinations and since, for the case of an equatorial orientation of the data base cube, it is a simple matter to regard the cube face coordinates of such datum points as zero within an arbitrary, but nonzero, distance from the pole.

It is emphasized that Equations (3-4), (3-5), and (3-6) yield two unique values for both θ' and ϕ', depending on the choice of $\pm\psi/2$; therefore, both halves of the scan arc are treated efficiently using the same auxiliary quantities ($\sin i$, $\sin \phi$, etc.).

The expressions just presented will be used in Section 3.2 in an algorithm employing a newly developed transformation to obtain data base coordinates of datum points. These results are also used in Section 3.3 in an algorithm designed to employ the older transformation of Section 2.2 to compute the data base coordinates of datum points in a computationally efficient manner.

3.2 POLAR FORMULATION OF THE AREA-PRESERVING TRANSFORMATION

Section 2 of Reference 1 presents an area-preserving transformation from the spherical square to the inscribed plane square. That transformation utilizes a central projection onto the plane square and a transformation from the projected

coordinates (ξ, η) to the data base coordinates (x, y). This transformation, designated by f*, is given in Equation (2-4) as

$$x = f^*(\xi, \eta)$$

$$y = f^*(\eta, \xi)$$

and is based on the Jacobian determinant. It was noted in Reference 1 that the solutions obtained to differential equations based on this determinant are not fully constrained by requiring the interior and edges of the spherical square to map onto the plane square. Additionally, it was found that, despite adding further constraints, no analytic solution could be found for f*. An approximate solution was arrived at using a numerical steepest descent method. Under the current contract, an alternative solution was studied; the results are presented below.

Two sets of polar coordinate systems are considered (Figures 3-3 and 3-4). Figure 3-3 shows a spherical square of radius R, produced by the central projection of an inscribed square upon the sphere. The polar coordinates (θ, ϕ) are defined by an axis of the sphere passing through the center of the spherical square and by a great circle arc passing through the axis and bisecting one edge of the square. The azimuthal angle, θ, is measured from this "meridian" and the central angle, ϕ, is measured from the axis. For the case where the coordinate axis and meridian coincide with those of the sphere, θ equals the longitude and ϕ is the colatitude.

Figure 3-4 shows a plane square of side $2r_o$. The axis in this system is normal to the plane, passes through the center of the plane, and has its origin at a distance r_o below the plane. Coordinates (μ, ν) are defined in the same sense as (θ, ϕ).

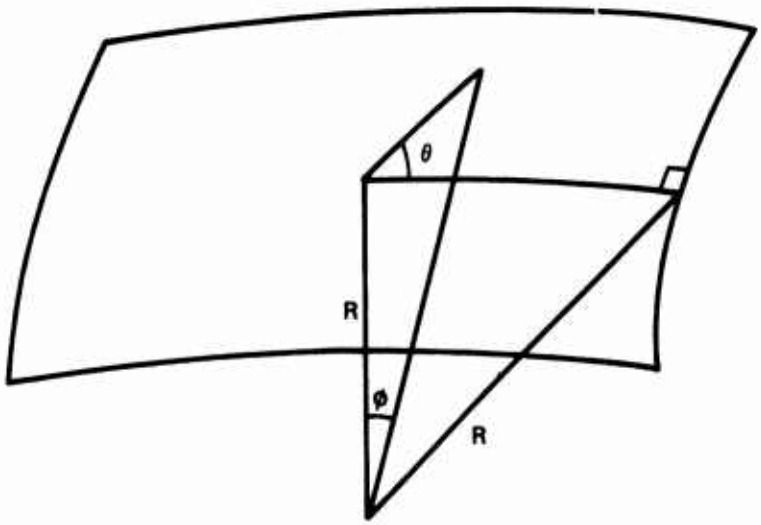


Figure 3-3. Polar Coordinate System on Spherical Square

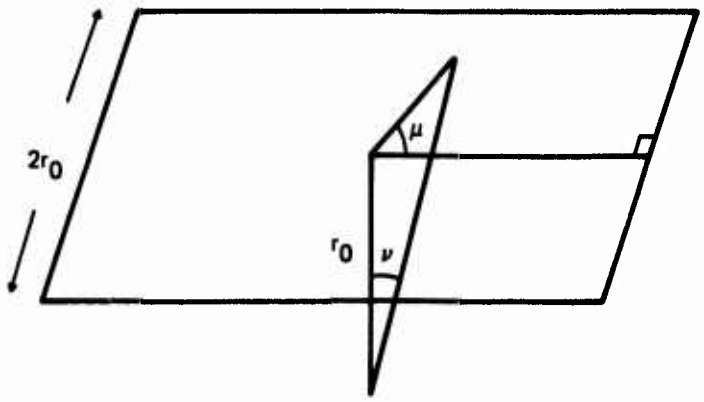


Figure 3-4. Polar Coordinate System on an Inscribed Plane

If the axes of the two systems are aligned and the plane square is inscribed within the spherical square, it can be shown that

$$r_o = R/\sqrt{3} \tag{3-7}$$

The area of the sphere is

$$A_s = 4\pi R^2 \tag{3-8}$$

and the surface area of the inscribed cube is

$$A_c = 24r_o^2 \tag{3-9}$$

The ratio of the areas of the spherical and plane squares is given by

$$\lambda = \frac{A_s}{A_p} = \frac{4\pi R^2}{24r_o^2} \tag{3-10}$$

Substituting Equation (3-7) into Equation (3-10) yields

$$\lambda = \pi/2 \tag{3-11}$$

To further constrain the mapping of the spherical square upon the plane, consider the condition $\mu = f(\theta)$, where μ is independent of ϕ. This condition implies the useful property that any great circle on the sphere passing through the center of the spherical square will map as a straight line passing through the center of the plane square. This function must be area preserving in the

sense that sectors of equal area on the sphere must map into equivalent areas on the plane. If the function f exists, then it is possible to relate the areas of differential elements $d\theta$ and $d\mu$ of the spherical and plane squares, as shown below.

To obtain the function $\mu = f(\theta)$, consider the right spherical triangle ABC in Figure 3-5, and let one side, B, be the meridian and A, the azimuth angle, θ. For a unit sphere, $R \equiv 1$ and $b = \pi/4$.

From the general relation for the area of a spherical triangle

$$S = R(A + B + C - \pi) \tag{3-12}$$

and the area of the right spherical triangle is

$$S_s = \theta + \beta - \pi/2 \qquad (c \equiv \pi/2) \tag{3-13}$$

By Napiers' identity, $B = \cos^{-1}(\sin A \cos b)$ and

$$S_s = \theta + \cos^{-1}(\sin \theta \cos \pi/4) - \pi/2 \tag{3-14}$$

This triangle may represent any segment of the spherical square in the range $-\pi/4 \leqq \theta \leqq \pi/4$.

The area of the corresponding right triangle on the plane (Figure 3-6) is

$$S_p = \frac{ar_o}{2} \tag{3-15}$$

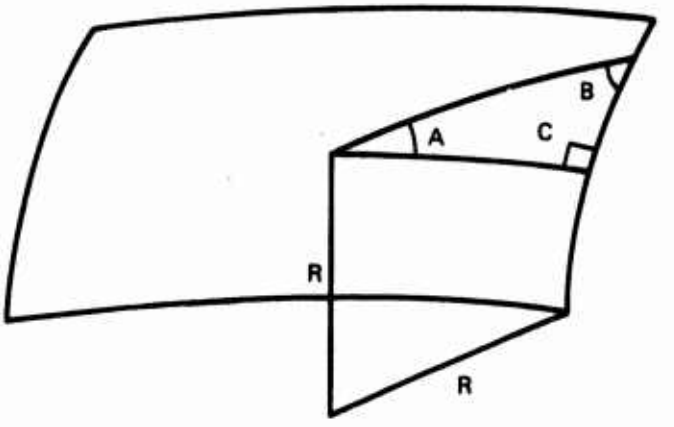


Figure 3-5. Right Spherical Triangle ABC

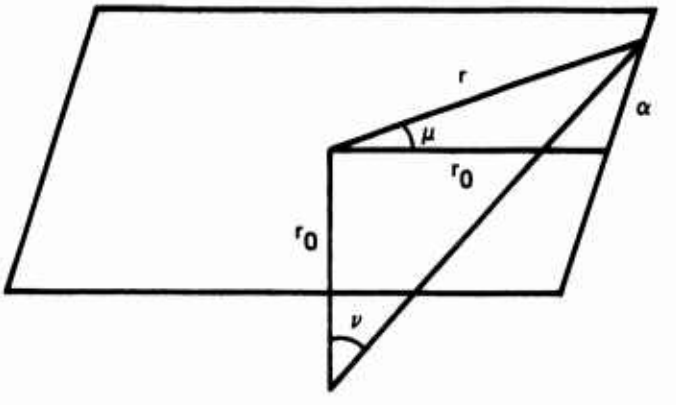


Figure 3-6. Plane Right Triangle Corresponding to ABC

or, since $a = r_o \tan \mu$,

$$S_p = \frac{r_o^2}{2} \tan \mu \tag{3-16}$$

For $\mu = f(\theta)$ to preserve area, the condition must hold that, for any θ,

$$S_s / S_p = \lambda \tag{3-17}$$

Thus,

$$S_s = \pi/2 \, S_p = \frac{r_o^2}{4} \tan \mu \tag{3-18}$$

and

$$\mu = \tan^{-1}\left(\frac{4}{\pi r_o^2} S_s\right) \tag{3-19}$$

In the case of a unit sphere, $r_o = 1/\sqrt{3}$, and

$$\mu = \tan^{-1}\left(\frac{12}{\pi} S_s\right) \tag{3-20}$$

$$\mu = \tan^{-1}\left\{\frac{12}{\pi}\left[\theta - \cos^{1}\left(\sin\theta \cos\frac{\pi}{4}\right) - \frac{\pi}{2}\right]\right\} \tag{3-21}$$

It can be shown that $\mu = 0$ at $\theta = 0$ and $\mu = \pm\pi/4$ at $\theta = \pm\pi/4$. The function f is defined over the quadrant $-\pi/4 \leqq (\theta, \mu) \leqq \pi/4$ and, by reflection, over the entire spherical and plane squares.

To relate ν and ϕ, expressions for the differential area elements, $\phi d\theta$ and $\nu d\mu$, must be obtained. Figure 3-7 illustrates a spherical zone of one base, having area

$$S_s = 2\pi Rh \tag{3-22}$$

Substituting $h = R - R \cos \phi$ and taking $R \equiv 1$ yields

$$S_s = 2\pi(1 - \cos \phi) \tag{3-23}$$

Since

$$S_s = \int_0^{2\pi} 1 - \cos \phi \, d\theta \tag{3-24}$$

$$dS_s = (1 - \cos \phi) \, d\theta$$

The area of the corresponding sector on the plane is given by

$$dS_p = r^2 d\mu \tag{3-25}$$

In order to apply the area-preserving condition, Equation (3-17) is differentiated to yield

$$dS_s = \pi/2 \, dS_p \tag{3-26}$$

Substituting Equations (3-24) and (3-25) into Equation (3-26) gives

$$r^2 du = 2/\pi \, (1 - \cos \phi) \, d\theta \tag{3-27}$$

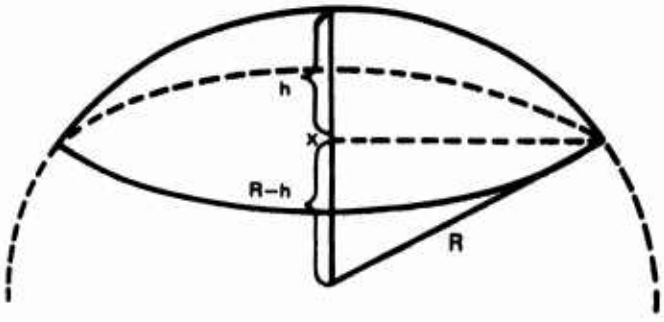


Figure 3-7. Spherical Zone of One Base

Since $r = r_o \tan \nu$, Equation (3-27) can be rewritten as

$$\tan^2 \nu = \frac{2}{\pi r_o^2} (1 - \cos \phi) \frac{d\theta}{du} \tag{3-28}$$

For fixed values of θ and u , Equation (3-28) becomes

$$\tan^2 \nu = C(1 - \cos \phi) \tag{3-29}$$

where

$$C = \frac{2}{\pi r_o^2} \frac{d\theta}{du}\bigg|_{\theta, u} \tag{3-30}$$

Clearly, C can be evaluated from boundary conditions:

1. When $\phi = 0$, $\nu = 0$ — points at the center map onto themselves

2. When $\phi = \phi_{max}$, $\nu = \nu_{max}$ — points on the boundary of the spherical square must map onto points on the boundary of the plane square

To develop these boundary conditions, it is necessary to obtain ϕ_{max} and ν_{max} as functions of θ and μ, respectively. Figures 3-8 and 3-9 illustrate these angles. It should be noted that to obtain the boundary of the spherical square, a central projection to the inscribed plane is employed. This projection preserves both θ and ϕ and reduces the problem to the case of the plane square.

The loci of points describing these edges can be expressed as

$$r_s = r_o \sec \theta \tag{3-31}$$

and

$$r_p = r_o \sec u \tag{3-32}$$

and the central angles can be expressed as

$$\phi_{max} = \tan^{-1} \sec \theta \tag{3-33}$$

and

$$\nu_{max} = \tan^{-1} \sec u \tag{3-34}$$

Substituting ϕ_{max} and ν_{max} in Equation (3-27)

$$\tan^2 \nu_{max} = C(1 - \cos \phi_{max}) \tag{3-35}$$

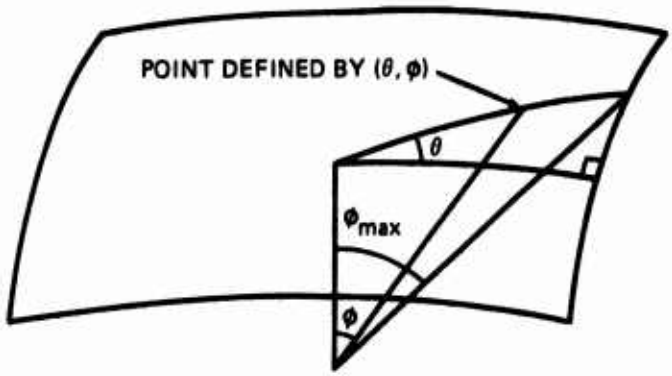


Figure 3-8. Relationship of ϕ_{max} to θ

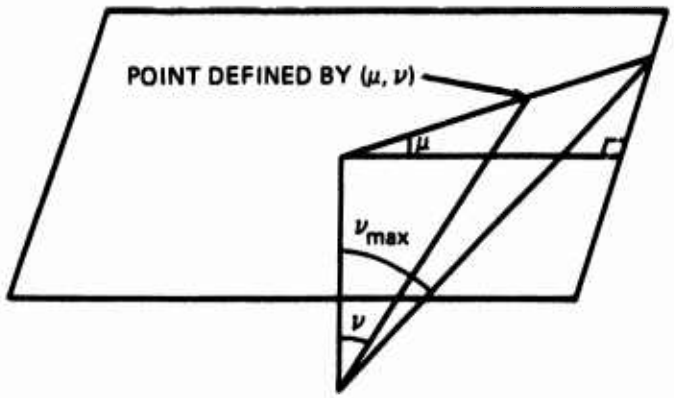


Figure 3-9. Relationship of ν_{max} to μ

Therefore

$$C = \frac{\tan^2 \nu_{max}}{1 - \cos \phi_{max}} = \frac{\tan^2 (\tan^{-1} \sec u)}{1 - \cos (\tan^{-1} \sec \theta)} = \frac{\sec^2 u}{1 - \cos (\tan^{-1} \sec \theta)} \quad (3\text{-}36)$$

Substituting C into Equation (3-35) yields

$$\tan^2 \nu = \frac{\sec^2 u}{1 - \cos \tan^{-1} \sec \theta} (1 - \cos \phi) \quad (3\text{-}37)$$

and

$$\nu = \tan^{-1} \sqrt{\frac{\sec^2 u (1 - \cos \phi)}{1 - \cos \tan^{-1} \sec \theta}} \quad (3\text{-}38)$$

This satisfies the boundary condition $\phi = 0$, $\nu = 0$, and additionally has the property that $\mu = 0$ at $\phi = 0$ and $\phi_{max} = \nu_{max}$, where $\theta = \pm\pi/4$, $u = \pm\pi/4$. This relation holds from $\phi = 0$ to $\phi = \pi/2$, and because ϕ_{max} is never greater than $\tan^{-1}\sqrt{2} = 0.95$, it is correct for the entire spherical square.

Thus, Equations (3-38) and

$$u = \tan^{-1}\left\{\frac{12}{a}\left[\theta + \cos^{-1}\left(\sin \theta \cos\frac{\pi}{4}\right) - \frac{\pi}{2}\right]\right\} \quad (3\text{-}39)$$

represent an area-preserving transformation from the spherical square to the inscribed plane square for the quadrant.

To treat the remaining quadrants, each is successively rotated into the quadrant of definition by subtracting multiples of $\pi/2$, as shown in Table 3-1.

Tab e 3-1. Rotations of θ and u' for a Given θ'[a]

Range	θ	u'
$-\frac{\pi}{4} \leq \theta' \leq \frac{\pi}{4}$	θ'	u
$\frac{\pi}{4} < \theta' \leq \frac{3\pi}{4}$	$\theta' - \frac{\pi}{2}$	$u + \frac{\pi}{2}$
$\frac{3\pi}{4} < \theta' < \frac{5\pi}{4}$	$\theta' - \pi$	$u + \pi$
$\frac{5\pi}{4} < \theta' < \frac{7\pi}{4}$	$\theta' - \frac{3\pi}{2}$	$u + \frac{3\pi}{2}$

[a]The quantities θ' and u' are input and output, respectively; and θ and u are as used in the computation of Equations (3-38) and (3-39).

3.3 REFINEMENT OF THE CARTESIAN TRANSFORMATION

Section 4.2 of Reference 1 outlines a method for obtaining the data base coordinates (x , y) of any datum point from Keplerian orbital elements, time, a scan angle, and parameters describing the attitude of the satellite using the inverse transformation, $f^*(\xi, \eta)$. This method has been modified in order to improve computational efficiency. The results are presented below in two parts: the first part treates the computation of the coordinates (x , y) of the subsatellite point (zero scan angle); the second part develops the necessary added formalism for datum points lying along a scan arc, as defined in Section 3.1.2. Details and derivations are included in Appendix C.

3.3.1 Data Base Coordinates of the Subsatellite Point

Computations for obtaining the data base coordinates (x , y) of the subsatellite point are performed as follows:

1. Evaluate Equation (3-1) for l , m , and n , and note the appropriate cube face by selecting the largest of l , m , and n and observing its sign. Table 3-2 establishes the necessary conventions. The general variables ξ' , η' , and ρ are the geocentric rectangular coordinates of the subsatellite point deduced from l , m , and n by entering Table 3-2, where ρ is the largest in absolute magnitude of l , m , and n .

2. Compute the variables α and β defined by:

$$\alpha = \xi'/\rho$$
$$\beta = \eta'/\rho \qquad (3\text{-}40)$$

Table 3-2. Cube Face Identification

Face Number	ξ'	η'	ρ
1	m	n	l
2	-m	n	-l
3	-l	n	m
4	l	n	-m
5	-l	-m	n
6	-l	m	-n

3. Compute x and y from

$$x = f^*(\alpha, \beta)$$
$$y = f^*(\beta, \alpha) \qquad (3\text{-}41)$$

where $f^*(\alpha, \beta)$ is developed in Appendix C. For convenience, the functional relationship is repeated below.

$$f^*(\alpha, \beta) = r_o \left\{ \alpha\gamma^* + \alpha^3 (1 - \gamma^*) + \alpha\beta^2 (1 - \alpha^2) \right.$$
$$\times \left[\Gamma + (\Gamma - M)(1 - \alpha^2) + (1 - \beta^2) \sum_{\substack{i \geq 0 \\ j \geq 0}} C_{ij} \alpha^{2i} \beta^{2j} \right] \qquad (3\text{-}42)$$
$$\left. + \alpha^3 (1 - \alpha^2) \left[\Omega_1 + (1 - \alpha^2) \sum_{i \geq 0} D_i \alpha^{2i} \right] \right\}$$

where α and β are defined by Equations (3-40), $r_o = 1/\sqrt{3}$, and the remaining constants are defined in Appendix C (Equations (C-10) and (C-11)).

3.3.2 Data Base Coordinates for Nonzero Scan Angle

The data base coordinates (x, y) for any pair of datum points lying on a scan arc at an angular separation of $\pm\psi/2$ from the subsatellite point are obtained by performing the following computational steps:

1. Obtain the geocentric longitude, θ, and colatitude, ϕ, of the subsatellite point using Equations (3-1) and (3-3). (If the ground trace has already been determined, its direction cosines will already have been computed from Equations (3-1).)

2. Compute the sines and cosines of the geocentric longitudes, θ', and colatitudes, ϕ', of the datum points, using Equations (3-4), (3-5), and (3-6), and the results of step 1.

3. Using the sines and cosines of θ' and ϕ' in Equations (3-3), obtain the two sets of direction cosines (l', m', and n') of the datum points.

4. Identify the appropriate cube face(s) and variables ξ', η', and ρ using Table 3-2, and compute values for α and β using Equations (3-40) for each point.

5. Calculate the (x, y) coordinates using Equations (3-41).

3.4 APPROXIMATE FORMS

The transformations outlined in the previous subsections share the common disadvantage of being complex and difficult to evaluate. While studying the transformations f and f* for the previous report, it was determined that a linear interpolation scheme was sufficient to find points between known benchmark grid points (Reference 1, Section 4.3). It is therefore evident that the transformation equation may be approximated by low-order polynomials. This subsection presents a method for accurately approximating the transformations over the entire cube face using polynomials of varying degree with locally evaluated and tabulated coefficients.

Because of symmetry properties of the transformations, it is necessary to evaluate the coefficients of the approximation polynomial over only one octant of one face. In addition, since

$$x = f(\xi, \eta);\ y = f(\eta, \xi)$$
$$\xi = f^*(x, y);\ \eta = f^*(y, x) \qquad (3\text{-}43)$$

only one set of coefficients is necessary to determine both x and y, and a second set to determine ξ and η.

From Table 4-2 of Reference 1, it can be seen that a double linear interpolation scheme will allow computation of intermediate points to an accuracy of 0.25 pixel over a range of at least 16 pixels (and up to 1024 pixels in the central region) on a 4096 x 4096 square. Consequently, it is reasonable to assume that a higher order polynomial would allow one-pixel accuracy over considerably greater distances. As a first approximation, it is assumed that determination and tabulation of coefficients on a grid with 64-pixel intervals will suffice. This interval is convenient, since it corresponds to the proposed standard data base record size.

To obtain suitable interpolating polynomials, the standard bivariate interpolation formulae were examined for three, four, and six points (Reference 4, Sections 25.2.65 to 25.2.67). From Figure 3-10, the formulae are

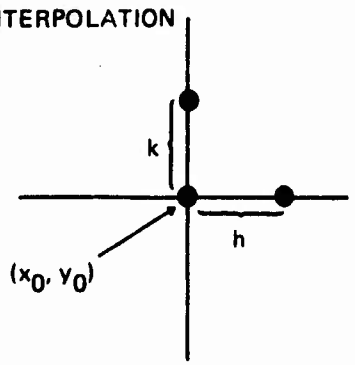
- Three Points (Linear)

$$f_a(x_0 + ph, y_0 + qk) = (1 - p - q) f_{0,0} + pf_{1,0} + qf_{0,1} + O(h^2) \qquad (3\text{-}44)$$

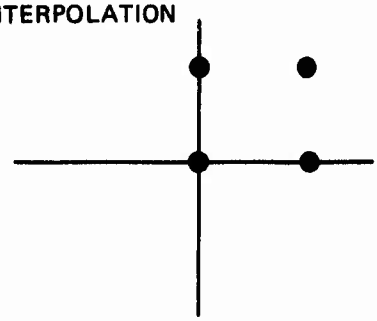
- Four Points

$$f_a(x_0 + ph, y_0 + qk) = (1 - p)(1 - q) f_{0,0} + p(1 - q) f_{1,0} + q(1 - p) f_{0,1} + pqf_{1,1} + O(h^2) \qquad (3\text{-}45)$$

a. THREE POINT INTERPOLATION



b. FOUR POINT INTERPOLATION



c. SIX POINT INTERPOLATION

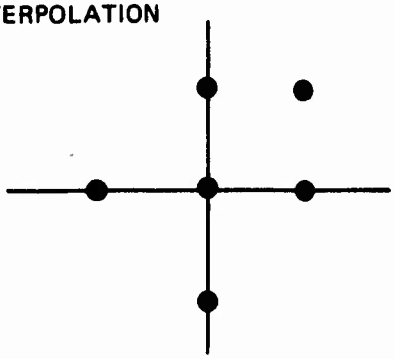


Figure 3-10. Grid Points Used for Interpolation

- Six Points

$$f_a(x_0 + ph, y_0 + qk) = \frac{q(q-1)}{2} f_{0,-1} + \frac{p(p-1)}{2} f_{-1,0} + (1 + pq - p^2 - q^2) f_{0,0} + \frac{p(p-2q+1)}{2} f_{1,0} + q(q-2p+1) f_{0,1} + pq f_{1,1} + O(h^3) \quad (3\text{-}46)$$

Equations (3-44) and (3-45) can be written as follows:

$$f_a(x,y) = a_{10} x + a_{01} y + a_{00} \quad (3\text{-}47)$$

$$f_a(x,y) = a_{11} xy + a_{10} x + a_{01} y + a_{00} \quad (3\text{-}48)$$

The coefficients a_{00}, a_{10}, ..., are evaluated by setting up a set of linear equations corresponding to the interpolation benchmark points and solving them simultaneously.

The six-point formula is less convenient to apply systematically, since it requires knowledge of points outside its range for solution. A compromise form

$$f_a(x,y) = a_{20} x^2 + a_{02} y^2 + a_{10} x + a_{01} y + a_{00} \quad (3\text{-}49)$$

can be evaluated on five points, as shown in Figure 3-11. This form eliminates the xy cross-product term and approximates the functional form with a paraboloid of revolution whose axis is perpendicular to the xy plane.

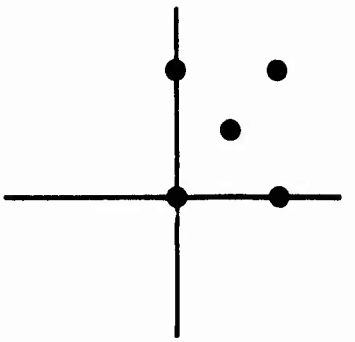


Figure 3-11. Five-Point Solution

A computer program was written to solve the system of simultaneous equations arising from each of the above approximate forms on 64 x 64 pixel intervals on one octant of the cube face (Figure 3-12). A standard IBM Scientific Subroutine Package (Reference 5) routine, SIMQ[1], was used for solution of the equations. To test the accuracy of each approximation, a set of evaluation points was chosen (Figure 3-13). The approximations were used successively to determine the coordinates of each evaluation point and a residual was computed for each point by solving the full transformation. Any 64 x 64 region in which the largest residual exceeded one pixel was flagged and the next higher degree approximation was tried. Table 3-3 shows the number of coefficients necessary for one pixel accuracy as a function of location.

The table size required is not excessive because, as stated above, only one octant (plus diagonal elements) must be stored. For a 64 x 64 grid, this would be

$$M \times (31^2 + 16) = M \times 977$$

[1] SIMQ employs the Gaussian elimination method using largest pivotal divisors.

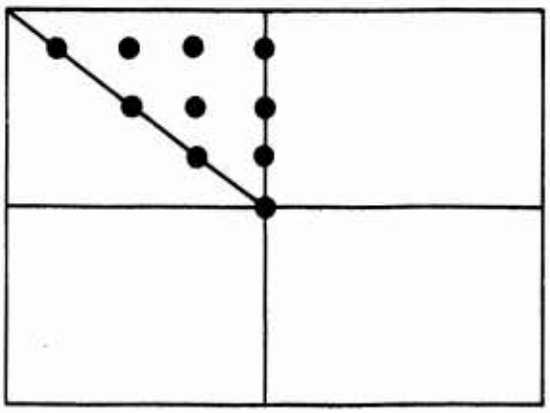


Figure 3-12. Origins of Coefficient Set Domains Necessary To Define Entire Face

Table 3-3. Number of Coefficients Necessary for One-Pixel Accuracy as a Function of Position

															4
														4	4
													3	4	4
												3	3	4	4
											3	3	3	3	4
										3	3	3	3	3	4
									3	3	3	3	3	3	3
								3	3	3	3	3	3	3	3
							3	3	3	3	3	3	3	3	3
						3	3	3	3	3	3	3	3	3	3
					3	3	3	3	3	3	3	3	3	3	3
				3	3	3	3	3	3	3	3	3	3	3	3
			3	3	3	3	3	3	3	3	3	3	3	3	3
		3	3	3	3	3	3	3	3	3	3	3	3	3	3
	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

4096, 4096

4096, 2048

2048, 2048

where M is the largest number of coefficients required. For the case where M = 5 , this requires 4885 words.

The program which evaluates the coefficients for the approximate direct transformation f_a is shown in Appendix E. Appendix D tabulates the coefficients derived and indicates the necessary number of coefficients for one-pixel accuracy. The use of these approximations will be discussed in Section 4.1.

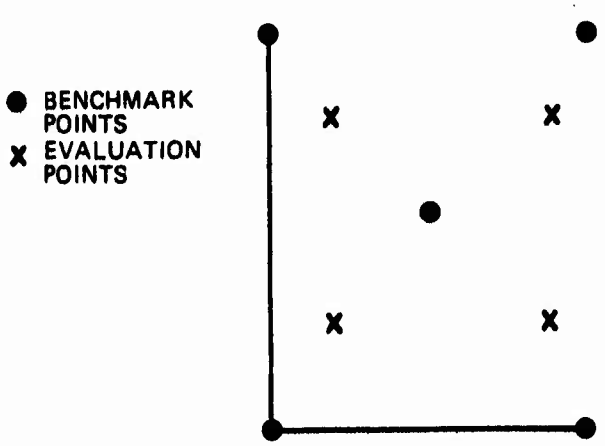


Figure 3-13. Arrangement of Evaluation Points

3.5 COMPARISON OF TRANSFORMATIONS

In the previous subsections, four different formulations were developed for the f* function (inverse transformation):

1. The original Cartesian form (Equation (2-5))
2. The revised Cartesian form (Equation (3-42))
3. The polar form (Section 3.2)
4. The approximate form (Section 3.4)

In choosing between forms 1 and 2, which produce the same mapping, form 2 is clearly arithmetically simpler and has proved to produce a more accurate determination of its coefficients.

Form 4 may be used to approximate the Cartesian or the polar forms and is the most efficient form computationally. It does, however, require core storage for the coefficient tables.

Figures 3-14 and 3-15 illustrate the differences in the nature of the mappings produced by the Cartesian and polar forms. The salient difference is that the polar form exhibits nondifferentiability at crossings of the diagonals of the face. This directional discontinuity arises from the condition that all great circles pass through the center of a face map as straight lines. This problem, in conjunction with the somewhat slower computation time shown in Table 3-4, favors the Cartesian form for most applications. The polar form retains the advantage of exactness in that it produces equal area to any desired accuracy

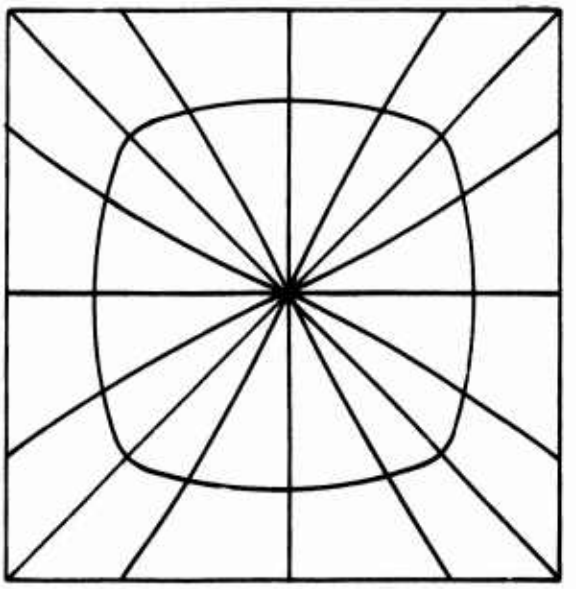


Figure 3-14. Distortions Arising From the Cartesian Form of the Transformation

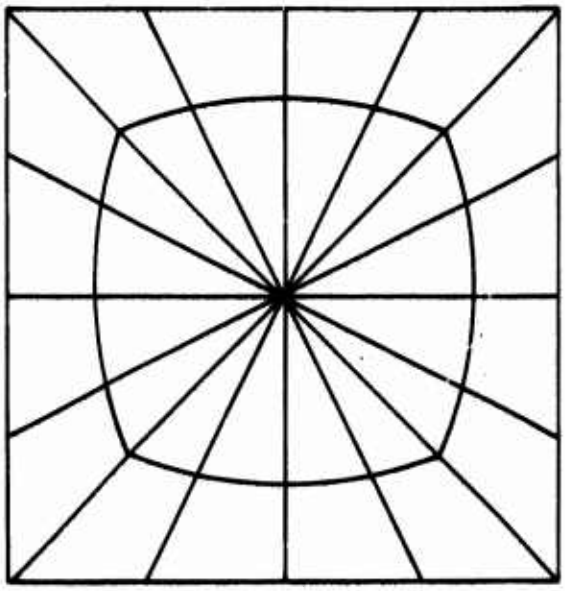


Figure 3-15. Distortions Arising From the Polar Form of the Transformation

Table 3-4. Execution Times for Transformation Forms on the IBM S/360-91 (One Ordered Pair)

Transformation	Execution Time (microseconds)
Cartesian	300
Polar	1000
Approximate	40

without recomputing the coefficients. It is difficult to compute coefficients that produce Cartesian transformations which will match retransformed points below the 2-nautical-mile level.

Both the Cartesian and polar formulations have their own uses: the Cartesian system at moderate resolutions and the polar system at the highest resolutions over small areas not including a diagonal. For benchmark transformations, the speed of either transformation is adequate, given a reasonably great interpolation distance. The high computational efficiency of the approximate forms tends to favor this approach for direct computation of data base coordinates (or for computation of corresponding points in the scan line buffer). This technique could also be particularly useful in the corner regions where interpolation is not accurate over useful distances.

SECTION 4 - I/O SYSTEM DESIGN CONSIDERATIONS

4.1 ALTERNATIVE METHOD OF FAST-FILLING

Section 2.3 briefly outlines a proposed alternative fast-filling scheme for the preprocessor program. This method, described in Reference 3, partially solves the problem of edge and vertex crossings and eliminates the necessity for explicit data spreading. By combining this approach with the approximation techniques descussed in this report, the overall efficiency of the preprocessor function can be increased still further.

Sections 3.1 and 3.3 present a method for obtaining data base coordinates (x, y) directly from Keplerian orbital elements and scanner angle. By omitting the last step of the process outlined in Section 3.3, positions in the (α, β) system can be obtained, which is simply a rescaled (ξ, η) system $(\alpha = \xi/r_o, \beta = \eta/r_o)$. Using this algorithm, a benchmark grid in (α, β) can be obtained and a procedure can then be followed which consists of a modification to that described in Reference 3. As outlined in Section 2.3 of Reference 3, filling is performed only for complete data base records (thus avoiding the necessity to read and update partially covered records). The procedure employs a new rotating Earth-centered coordinate system (x^R, y^R, z^R) in which both scanner and data base benchmarks are defined. CSC proposes modifying this procedure as follows:

1. Instead of using the x^R, y^R, z^R system, both scanner and benchmark grids in a coplanar system should be defined, projecting the scan line grid into the inscribed cube face and transforming the data base coordinates to the same (α, β) system.

2. The data base benchmarks should be defined in terms of the projected scanner benchmarks (i.e., the (E, L) coordinates of the data base benchmarks should be defined as shown in Figure 4-1).

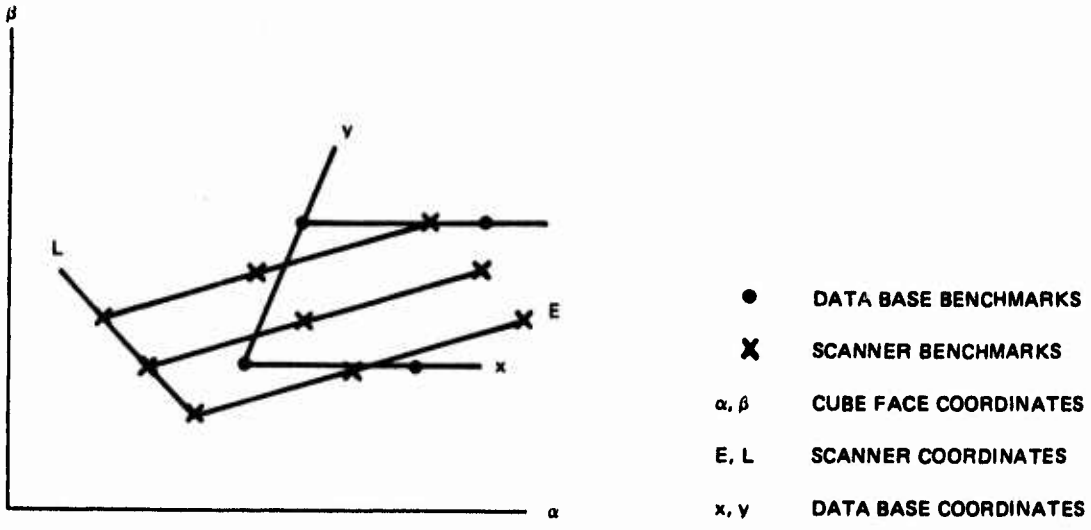


Figure 4-1. Coplanar Representation of Scanner and Data Base Grids

3. The (E, L) coordinates of each data base location should be interpolated and the nearest pixel stored in that location. (This may be done by offsetting the (E, L) system 1/2 pixel in both coordinates and obtaining E and L indices of the desired pixel by truncation.)

The objective of this modification is to avoid the necessity of searching for the nearest pixel in a three-dimensional space.

Neither this method nor the procedure in Reference 3 completely eliminates the edge and vertex crossing problems. It is necessary to predetermine, from the benchmarks of the scanner array, which data base records will be completely covered by the scanner data currently in the input buffer. This process must check for edge and vertex crossings.

Figure 4-2 illustrates the relationship between the scanner data input buffer and the data base records. The scan buffer must have sufficient length (in the along-track direction) to cover the longest diagonal of a data base record. For the 64 x 64 pixel case, this will be approximately 128 pixels in the corners of

the face. The scan line buffer must be organized as a creeping buffer, and no more lines may be added in the forward direction (and deleted in the backward direction) than the number of lines by which the buffer exceeds the minimum needed to cover the longest diagonal. A typical scanner input buffer would have a width (along the scan direction) of approximately 1600 nautical miles (about 1344 pixels), with a minimum length (in the ground track direction) of 128 pixels. This will require sufficient buffer storage for 172,032 pixels. Two methods emerge for handling this large array. The first is to pack more than one pixel per 60-bit word. This would allow the entire buffer to be maintained in central memory on the CYBER/175 but would introduce a large packing and unpacking cost. A second method would be to maintain the buffer in ECS, segmented so that it could be brought into core in blocks as required. The scheduling of these blocks, along with the ordering of output records, could be determined from

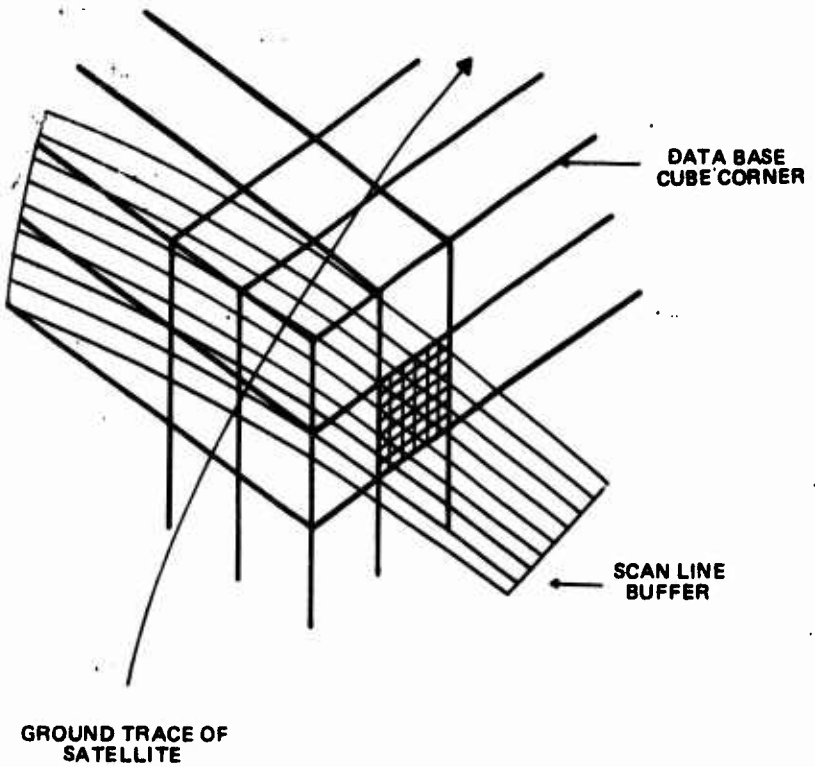


Figure 4-2. Relationship of Scanner Input Buffer and Data Base Records

the (x , y) locations of the projected and transformed scanner input benchmark grid, ordering the filling of data base records by their corresponding along-scan locations.

Because the objective of this new method is to reduce redundant stores, it could also be useful to consider windowing down the along-scan length of the input buffer as a function of latitude to reduce scan path overlap at high latitudes. Similarly, at low latitudes, it may be necessary to subdivide data base records into two or more longitude bands and partially update the records rather than fully rewriting them.

4.2 MAINTENANCE OF MULTIPLE- AND VARIABLE-RESOLUTION DATA BASES

Considerable savings in computation and I/O time and in data base storage can be realized by reducing the resolution of the data base in areas of lesser interest (such as, perhaps, over land and in the southern hemisphere). It may also be desirable to be able to maintain higher resolution for other selected areas. One method for providing such variable resolution coverage consists of maintaining a single, fully global data base at the lowest desired resolution, plus separate higher resolution partial data bases. A second method consists of maintaining a single data base of variable resolution.

In either case, it will be necessary to provide a system for indicating the desired resolution as a function of global position. This can be provided for by establishing a data block properties table (for example at the 128 x 128 or 256 x 256 element level) which would contain the desired resolution described as a multiple of the finest usable resolution or by the number of bits required for the serial address. This would allow the preprocessor program to determine the desired resolution at any point.

For the multiple data base scheme, the preprocessor program would first determine which elements of the resolution table are covered by the data currently in the scan line buffer and then access the table to determine what actions must

be taken. This table would consist of entries for each of the desired resolution levels indicating

- The desired resolution
- A base address for the block of records corresponding to the table element
- The size of the data base records (in elements)

The resolution and record size for all records in a block corresponding to one table element can both be expressed as a number of bits to be added to the corresponding binary division levels of the basic global data base, i.e., if the desired resolution is twice the linear resolution of the basic data base, two more address bits must be added and, if the records are to have the same number of elements, the record/element division of the serial string must take place two bits lower.

The serial string for each resolution level would be kept separate, and the use of a base address for each record block would obviate any need for unused filler records in the data base. For maximum flexibility, each resolution level could be maintained as a separate file.

With multiple data bases, the size of a data base record would be adjustable to allow an optimum match of record size to scanner input buffer size and data item size (where one data item might be all of the simultaneously available, colocated scanner readings). To maintain this match, a separate pass through the data will be required for each resolution level.

In the variable resolution approach, only one pass through the data is required and all data records cover the same area. This means that the ratio of the scanner buffer size to the data record area remains fixed, as do the total number of I/O operations. The total number of data records remains constant; thus, a consistent record numbering and ordering can be maintained, avoiding

the necessity of a table lookup for a block address, as in the multiple data base scheme. In this case, the data block lookup table need contain only the resolution (which will also imply the record length).

Both of the above schemes have advantages and disadvantages:

- The multiple data base scheme requires redundant stores and computation
- The variable resolution scheme requires stringing together unlike data base records, thus requiring a variable record length capability
- The multiple data base scheme allows easy addition or deletion of nonstandard resolution areas for coverage of new areas of interest
- The variable resolution scheme allows more systematic control over the data base storage allocations

A possible resolution of these conflicts is to use a hybrid system in which the variable resolution format would be used for resolutions coarser than a set standard resolution level, and the multiple data base approach for higher resolution levels (and for other subdata bases required for special purposes or limited durations).

A unified block properties table would be maintained which would allow display of the current status and availability of a data record in the system. This table could be expanded to include such information as the last update time, satellite ID, dayside/nightside information, etc. The advantages of such a scheme would be that multiple passes through the data would be restricted to selected regions of highest resolution, special changes in data base content could be accomplished without restructuring the main data base as a whole, systematic control over the entire data base could be maintained, and the serial string addressing scheme would be maintained for the standard resolution data.

SECTION 5 - GEOGRAPHIC ORIENTATION

5.1 INTRODUCTION

In order to maximize the usefulness and efficiency of the spherical cube data base, it may be necessary to orient the inscribed cube in some arbitrary manner with respect to the Earth. The simplest orientation of the cube aligns one Cartesian axis of the cube coordinate system with the Earth's axis of rotation and points another cube axis toward the prime meridian. A simple variation is to have one cube axis aligned with the Earth's axis of rotation and another pointing to a specified longitude. This section will discuss these orientations and will present an algorithm for producing arbitrary cube rotations.

5.2 SIMPLE ORIENTATIONS

In Section 4.2 and Appendix E.6 of Reference 1, algorithms are presented for the transformation of Earth-centered Cartesian coordinates (a , b , c) to data base coordinates (x , y) . For the case where the Earth-centered (a , b , c) system is aligned as shown in Figure 5-1, the Cartesian coordinates can be represented as:

$$a = \cos(\text{latitude}) \cos(\text{longitude}) \tag{5-1}$$

$$b = \cos(\text{latitude}) \sin(\text{longitude}) \tag{5-2}$$

$$c = \sin(\text{latitude}) \tag{5-3}$$

To accomplish a simple rotation about the Earth's polar axis, the following algorithms can be used:

$$a = \cos(\text{latitude}) \cos(\text{longitude} + \delta) \tag{5-4}$$

$$b = \cos(\text{latitude}) \sin(\text{longitude} + \delta) \tag{5-5}$$

$$c = \sin(\text{latitude}) \tag{5-6}$$

where δ represents the angle of rotation.

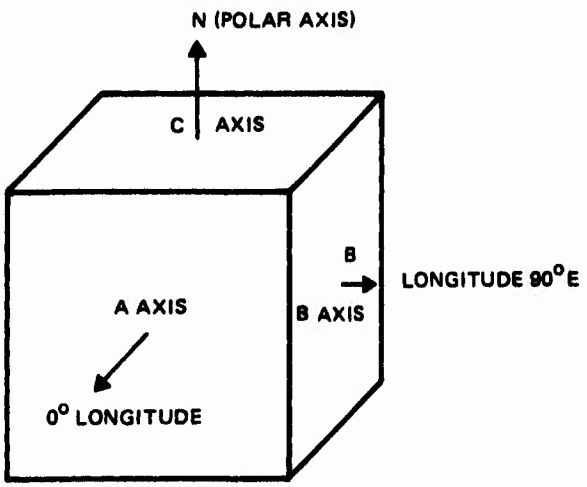


Figure 5-1. Orientation of the Axes of the Cube (Unrotated)

5.3 THE GENERAL ROTATION CASE

In order to conveniently generate arbitrary rotations of the data base cube with respect to the sphere, a method was adopted for making successive rotations of the sphere about each of the axes of the cube. By choosing the order in a suitable manner, this yields a conceptually simple way of arriving at a given orientation.

Taking a general set of orthogonal axes, G_1 , G_2 , G_3 , as shown in Figure 5-2, the rotation about axis G_1 can be expressed as follows:

Let α be the desired angle of rotation about G_1 . For any arbitrary point, g_1 , g_2 , g_3 , the position may be expressed in terms of the following three variables:

- g_1 , the G_1 coordinate
- β , the angular position of the projection of g_1 , g_2 , g_3 on the G_2G_3 plane measure from G_3 in the clockwise sense
- ρ , the perpendicular distance from g_1 , g_2 , g_3 to the G_1 axis

For a pure rotation about G_1 (Figure 5-3), g_1 and ρ are constant and the final orientation, g_1' , g_2' , g_3' , is determined by the new orientation angle, γ , where

$$\gamma = \alpha + \beta \tag{5-7}$$

and since

$$\beta = \tan^{-1} (g_3/g_2) \tag{5-8}$$

then

$$\gamma = \alpha + \tan^{-1} (g_3/g_2) \tag{5-9}$$

where

$$\rho = g_2^2 + g_3^2 \tag{5-10}$$

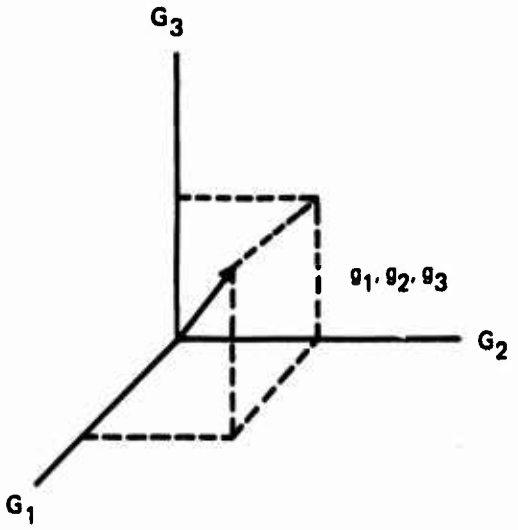


Figure 5-2. Point g_1 , g_2 , g_3 in the General Reference Frame, G_D , G_2 , G_3

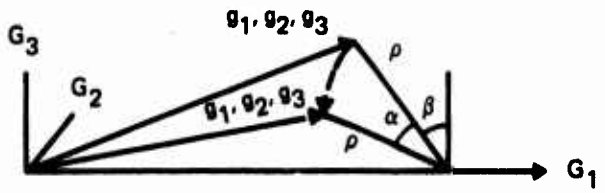


Figure 5-3. Rotation of the Point (g_1 , g_2 , g_3) About the G_1 Axis

yielding

$$g_1' = g_1 \tag{5-11}$$

$$g_2' = \rho \cos \gamma \tag{5-12}$$

$$g_3' = \rho \sin \gamma \tag{5-13}$$

Using this general approach, a rotation through an angle α_1 is first made about the axis coincident with the Earth's axis of rotation. This is functionally equivalent to the rotation described in Section 5.1 and results in a rotation of the α_1 longitude line into the center of face number 1.

The second rotation is made about the axis normal to the pole and emerging through a face normal to face number 1 (axis b in Figure 5-1). If this rotation is through an angle α_2, then the point with longitude α_1 and latitude α_2 will be rotated into the center of face 1.

A third rotation about the axis emerging from the center of face 1 will produce a "position angle" change on face 1 but will not translate the point at the center of the face.

Using this method, any point whose latitude and longitude are known may be translated to the center of face 1 and the rotational aspect of that face may be altered without changing the latitude and longitude of the center. Referring to Figure 5-1, the order of these rotations is about axes c, b, and a, respectively.

Appendix E contains an algorithm for the application of the general transformation to successive axes through the interchange of components.

Figures 5-4 and 5-5 illustrate the continental outlines after the indicated rotations and are typical of maps generated by this process.

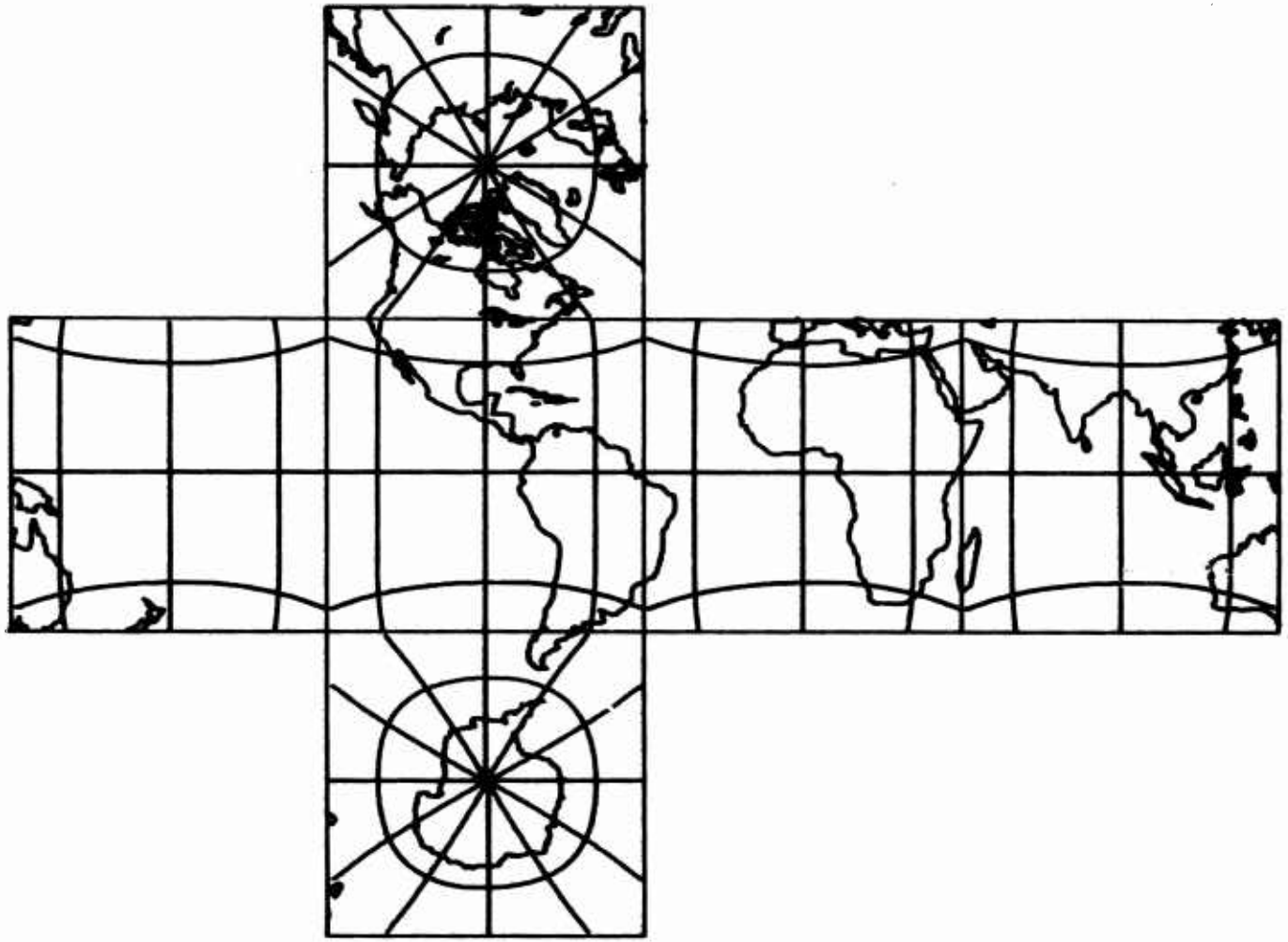


Figure 5-4. Data Base Map of Earth With Cube Oriented 90 Degrees West of Greenwich

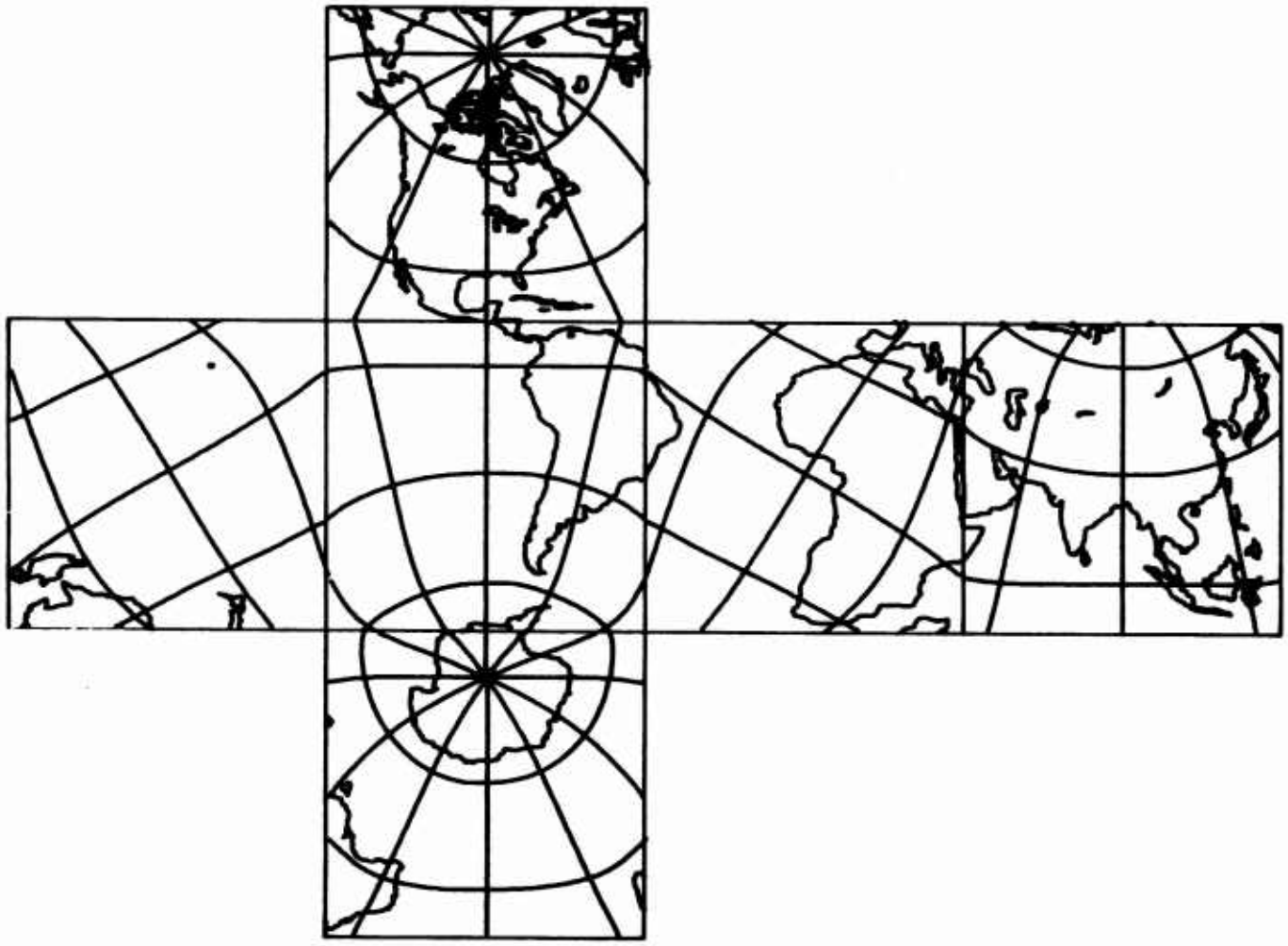


Figure 5-5. Data Base Map of Earth With Cube Oriented 90 Degrees West of Greenwich and 30 Degrees South of the Equator

SECTION 6 - SUMMARY AND CONCLUSIONS

6.1 NEW RESULTS

The purpose of the research reported herein is to improve the procedures and algorithms required for the efficient maintenance of data in a quadrilateralized spherical cube Earth data base. The new results obtained relate to the fast-filling of the data base. A technique was developed for rapidly finding the ground trace and scanner-sensed locations from Keplerian elements and scanner angle. The previously derived form of the inverse transformation, f^*, was improved by a change of variables. A new inverse transformation was derived using polar coordinates, and a technique was developed for approximating the transformation functions using low-order polynomials.

All of these results will contribute to improving the accuracy and speed of the preprocessor function. The general functioning of the preprocessor input/output algorithms was re-examined in light of an alternative scheme (Reference 3). This scheme and the previously developed fast-filling method (Reference 1) were compared, and a modification of the scheme described in Reference 3 is recommended.

In addition, improved world maps in data base coordinates were produced for use in determining an optimum orientation of the data base cube. Additional efforts were devoted to improving the accuracy of the transformations described in Reference 1. The revised coefficients for these transformations are included in Appendix B of this report.

6.2 RECOMMENDATIONS FOR FURTHER STUDY

A number of topics considered during this study are worthy of additional attention. The polar formulations of the transformation functions should be further developed using other constraints to maximize conformality of the mapping.

The role of the MAP III processor in implementing the preprocessor function was excluded from this study because documentation is not available. The role which MAP III and the high-speed communications system's processor could assume in evaluating the transformation equations, particularly the approximate transformation, should be explored further.

The various CYBER I/O access methods should be studied further, particularly to ascertain whether or not they may cause fragmentation of the data base.

Consideration should be given to producing display output in data base coordinates with a geographic grid overlay, thereby saving a major computation cost in retransforming the data.

APPENDIX A - GROUND TRACE EQUATIONS

This appendix presents the derivation of the expressions summarized in Section 3.1 and referred to elsewhere in this document. Two problems are addressed: (1) the computation of the geocentric direction cosines (l, m, n) of the subsatellite point in terms of the Keplerian orbital elements of the satellite and (2) the computation of the geocentric longitudes and colatitudes of any pair of datum points on a scan arc in terms of previously computed quantities (e.g., l, m, n). A spherical Earth is assumed throughout.

A.1 THE SUBSATELLITE POINT

Figure A-1 shows the geometric relationship of the satellite, the satellite's orbit, and the Earth's equator to the (rotating) rectangular coordinate system (x, y, z). The coordinate system is fixed in the Earth and, therefore, rotates at the diurnal rate. The Keplerian orbital elements whose definitions are given by the figure are the inclination, i; the argument of perigee, ω, shown as part of the angle $(\omega + f)$, where f is the satellite's true anomaly; and the node, Ω, which is not the usual fixed quantity, but varies with the sidereal time (diurnal rate), s, as follows:

$$\Omega = \Omega_o - s \qquad \text{(A-1)}$$

where Ω_o is the value of Ω at an arbitrary initial time.

Figure A-1 shows the subsatellite point having geocentric coordinates longitude, θ, and colatitude, ϕ, and lying, by definition, on the line joining the satellite and the Earth's center. Therefore, the direction cosines (l, m, and n) describing the direction to the satellite in the x, y, z system are identical with those for the subsatellite point. The straightforward relationship between the direction cosines and θ and ϕ will be exploited in Section A.2. First, the

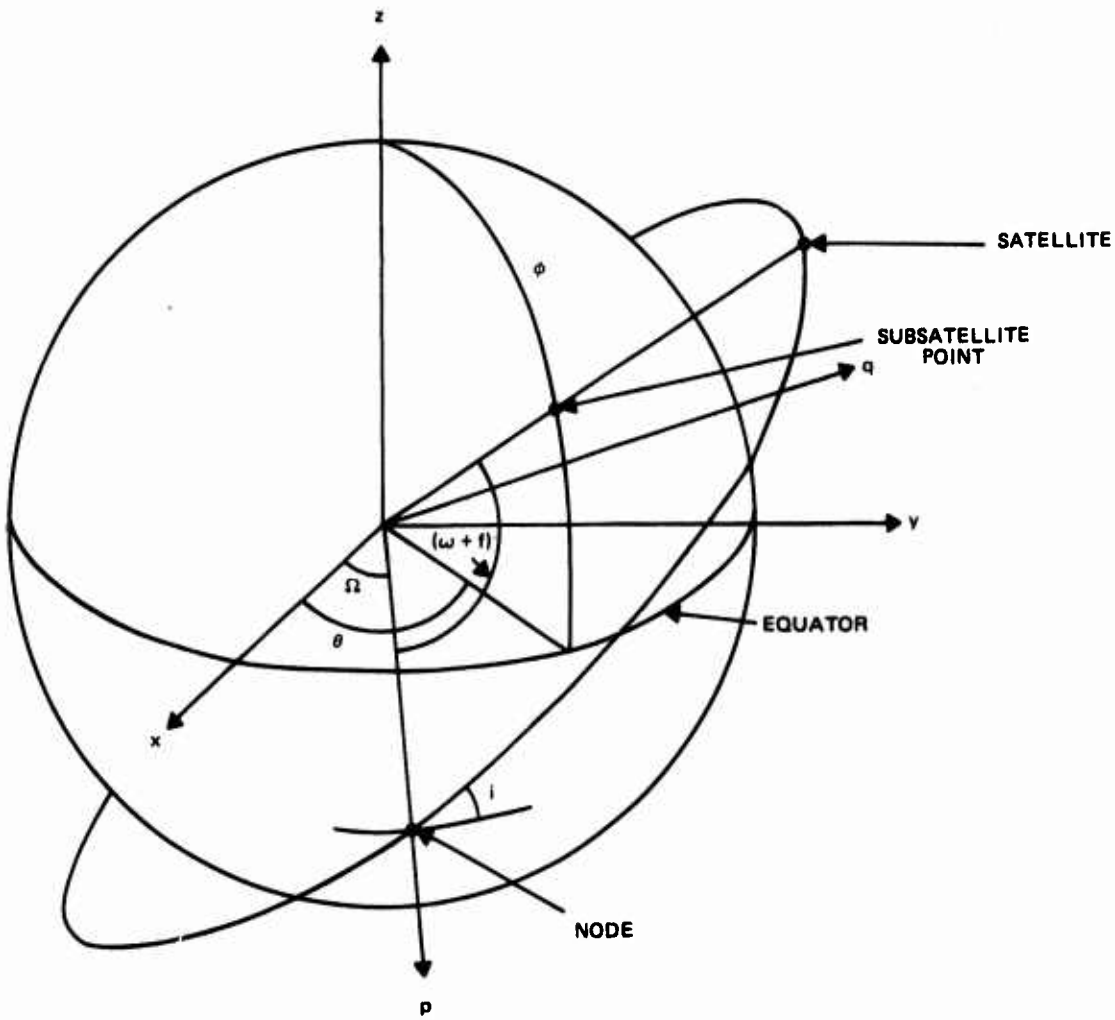


Figure A-1. Satellite Orbit Orientation and Geographic Coordinates

expressions for l, m, and n in terms of Ω, ω, i, and f are derived below.

Consider the geocentric position vector, $\vec{r}$, of the satellite in its orbit. Express $\vec{r}$ in the two-dimensional rectangular coordinate system $(\hat{p}, \hat{q})$ in the orbital plane, where the unit vector $\hat{p}$ is in the direction of the node and the unit vector $\hat{q}$ is in the direction 90 degrees in advance of $\hat{p}$ (see Figure A-1)

$$\vec{r} = r \cos(\omega + f)\,\hat{p} + r \sin(\omega + f)\,\hat{q}$$

where r is the magnitude of $\vec{r}$. The coordinates (r_x, r_y, r_z) of the satellite in the geocentric equatorial rectangular coordinate system are, then,

$$\begin{aligned} r_x &= \vec{r} \cdot \hat{x} = r \cos(\omega + f)\,\hat{p} \cdot \hat{x} + r \sin(\omega + f)\,\hat{q} \cdot \hat{x} \\ r_y &= \vec{r} \cdot \hat{y} = r \cos(\omega + f)\,\hat{p} \cdot \hat{y} + r \sin(\omega + f)\,\hat{q} \cdot \hat{y} \\ r_z &= \vec{r} \cdot \hat{z} = \qquad\qquad + r \sin(\omega + f)\,\hat{q} \cdot \hat{z} \end{aligned} \tag{A-2}$$

where the term in $\hat{p} \cdot \hat{z}$ for r_z is omitted, since $\hat{p} \cdot \hat{z} = 0$.

Now,

$$\begin{aligned} \hat{p} \cdot \hat{x} &= \cos \Omega \\ \hat{q} \cdot \hat{x} &= \cos(90^\circ + \Omega) \cos i = -\sin \Omega \cos i \\ \hat{p} \cdot \hat{y} &= \sin \Omega \\ \hat{q} \cdot \hat{y} &= \sin(90^\circ + \Omega) \cos i = \cos \Omega \cos i \\ \hat{q} \cdot \hat{z} &= \cos(90^\circ - i) = \sin i \end{aligned} \tag{A-3}$$

Substituting Equations (A-3) into Equations (A-2), r_x, r_y, and r_z become

$$\begin{aligned} r_x &= r \cos \Omega \cos (\omega + f) - r \sin \Omega \sin (\omega + f) \cos i \\ r_y &= r \sin \Omega \cos (\omega + f) + r \cos \Omega \sin (\omega + f) \cos i \\ r_z &= r \sin (\omega + f) \sin i \end{aligned} \tag{A-4}$$

Since the satellite position vector, $\vec{r}$, in the $(\hat{x}, \hat{y}, \hat{z})$ system is

$$\vec{r} = r_x \hat{x} + r_y \hat{y} + r_z \hat{z} \tag{A-5}$$

the direction cosines (l, m, n) of its position are defined by

$$\begin{aligned} \vec{r} \cdot \hat{x} &= |\vec{r}| \, |\hat{x}| \, l \\ \vec{r} \cdot \hat{y} &= |\vec{r}| \, |\hat{y}| \, m \\ \vec{r} \cdot \hat{z} &= |\vec{r}| \, |\hat{z}| \, n \end{aligned} \tag{A-6}$$

Now, from Equation (A-5),

$$\vec{r} \cdot \hat{x} = r_x \hat{x} \cdot \hat{x} = r_x$$

$$\vec{r} \cdot \hat{y} = r_y \hat{y} \cdot \hat{y} = r_y$$

$$\vec{r} \cdot \hat{z} = r_z \hat{z} \cdot \hat{z} = r_z$$

which, when substituted into Equations (A-6), yields

$$l = r_x/|\vec{r}|\,|\hat{x}| = r_x/r$$

$$m = r_y/|\vec{r}|\,|\hat{y}| = r_y/r \qquad \text{(A-7)}$$

$$n = r_z/|\vec{r}|\,|\hat{z}| = r_z/r$$

since $|\hat{x}| = |\hat{y}| = |\hat{z}| = 1$, and $|\vec{r}| = r$.

Equations (A-4) and (A-7) then yield

$$l = \cos \Omega \cos(\omega + f) - \sin \Omega \sin(\omega + f) \cos i$$

$$m = \sin \Omega \cos(\omega + f) + \cos \Omega \sin(\omega + f) \cos i \qquad \text{(A-8)}$$

$$n = \sin(\omega + f) \sin i$$

Equations (A-8) provide one way of defining the "ground trace" of the satellite, since l, m, and n may be regarded as the "unit" geocentric coordinates of the subsatellite point. That is, assuming a spherical Earth, the actual coordinates of the subsatellite point are obtained by multiplying l, m, and n by the Earth's radius in whatever units are required (e.g., kilometers). Equation (A-8) is given as Equation (3-1) in the text.

A.2 THE LOCATION OF DATUM POINTS ON A SCAN ARC

The satellite's onboard sensors are assumed to sweep out a scan arc having ground trace geometric properties as defined in Section 3.1.2 and as illustrated in Figure A-2. It is convenient to regard the ground trace of the scan arc as being composed of pairs of datum points symmetrically placed on either side of the subsatellite point, and to regard $\psi/2$ as a general variable locating the points by assigning alternate algebraic signs to $\psi/2$ (e.g., the ends of the

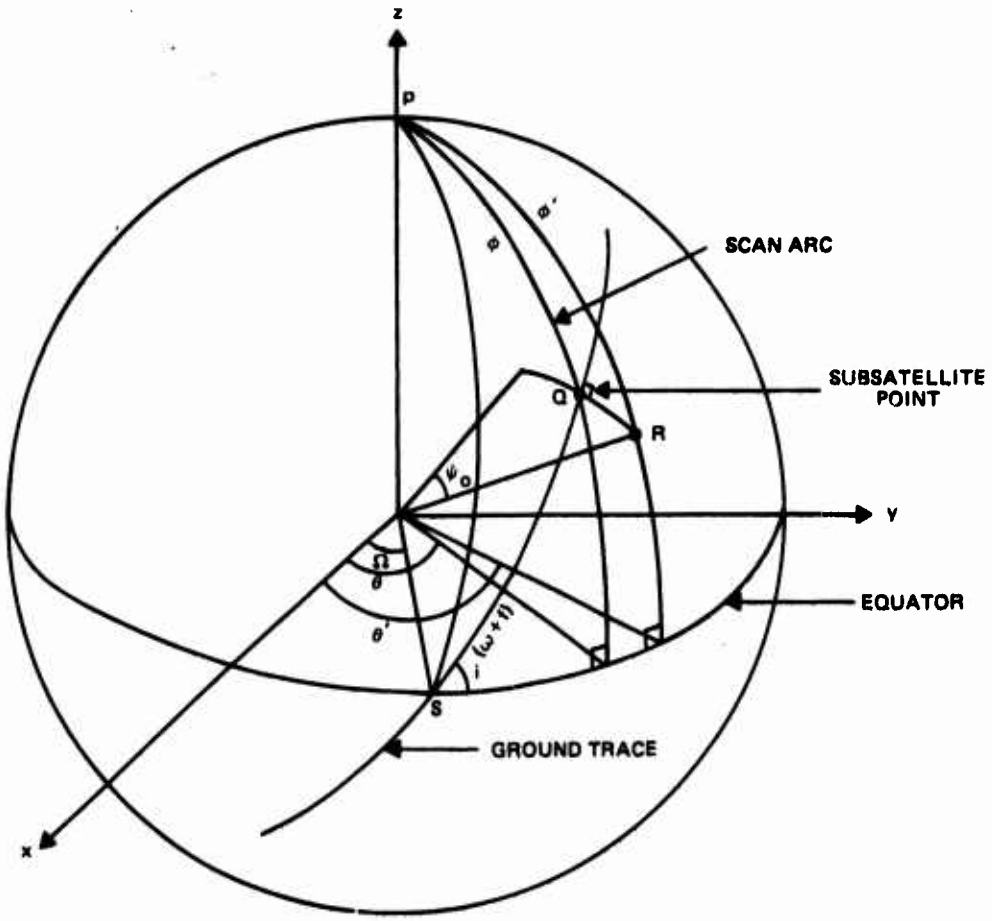


Figure A-2. The Scan Arc as a Central Angle ψ_o

scan arc are located at $\pm\psi_o/2$ from the subsatellite point). It is desired to obtain pairs of values for the geocentric longitude, θ', and colatitude, ϕ', of the datum points in terms of known quantities in a computationally efficient manner.

The sines and cosines of the geocentric longitude, θ, and colatitude, ϕ, of the subsatellite point are required as intermediate quantities in terms of l, m, and n from Equations (A-8). By inspection of Figure A-1,

$$\begin{aligned} \cos\theta \sin\phi &= l \\ \sin\theta \sin\phi &= m \\ \cos\phi &= n \end{aligned} \qquad \text{(A-9)}$$

Care must be taken in using Equations (A-9) to obtain $\sin\phi$, $\cos\phi$, $\sin\theta$, and $\cos\theta$, since the algebraic signs of these quantities must be preserved for later use. This is readily achieved by noting that $\cos\phi$ yields ϕ uniquely, since $0 \le \phi \le 180$ degrees. Straightforward manipulation yields the remaining quantities. Equation (A-9) is given in the text as Equation (3-3).

To obtain the values of ϕ', the necessary relations may be derived by considering the two spherical triangles PSQ and PQR shown in Figure A-2 and having the common side PQ, which is the colatitude, ϕ, of the subsatellite point. These triangles are shown in detail in Figure A-3, where it is noted that the arc PS is 90 degrees, that the scan arc intersects the ground trace at right angles, and that point R' may be regarded as any point on the scan arc at a distance of $\psi/2$ from the subsatellite point, Q. (Figure A-2 shows only the end point of the scan arc, R, at a distance $\psi_o/2$ from the subsatellite point.) Also shown in Figure A-3 are two auxiliary angles, A and β, such that $A + \beta + 90$ degrees = 360 degrees.

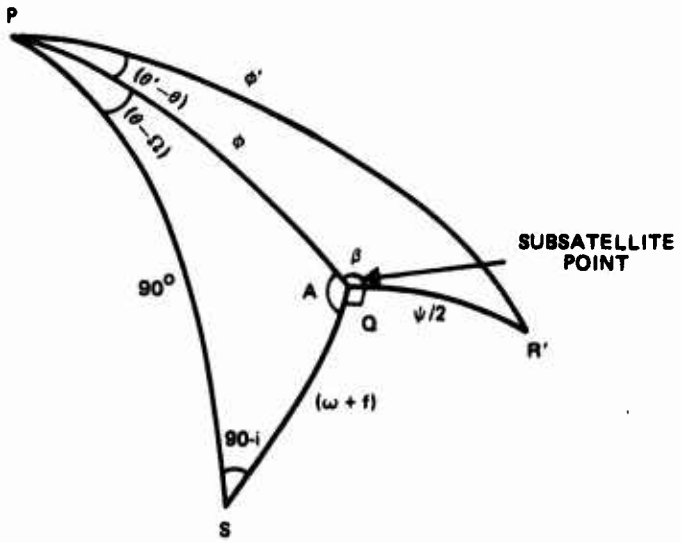


Figure A-3. Two Adjoining Spherical Triangles and the Subsatellite Point Q

The cosine law applied to triangle PQR' yields

$$\cos \phi' = \cos \phi \cos \psi/2 + \sin \phi \sin \psi/2 \cos \beta \qquad \text{(A-10)}$$

Since $\psi/2$ is a quantity given a priori, all of the quantities to the right of the equality in Equation (A-10) are known except $\cos \beta$, which is obtained as follows.

By definition

$$\beta = 270^{\circ} - A$$

Therefore

$$\cos \beta = \cos (270^{\circ} - A) = \cos (270^{\circ}) \cos A + \sin (270^{\circ}) \sin A$$
$$= -\sin A \qquad \text{(A-11)}$$

Applying the sine law to triangle PSQ,

$$\frac{\sin A}{\sin 90^{\circ}} = \frac{\sin (90^{\circ} - i)}{\sin \phi}$$

or (A-12)

$$\sin A = \cos i/\sin \phi$$

Employing Equations (A-11) and (A-12) in Equation (A-10) yields

$$\cos \phi' = \cos \phi \cos \psi/2 - \cos i \sin \psi/2 \qquad \text{(A-13)}$$

which is the desired relation for $\cos \phi'$. Equation (A-13) yields ϕ' uniquely, since $0 \leq \phi' \leq 180$ degrees , so that $\sin \phi'$ follows immediately. By appropriately redrawing Figure A-3 and repeating the above analysis, it can be readily seen that ϕ' for the datum point corresponding to $-\psi/2$ on the other half of the scan arc is obtained from Equation (A-13) simply by replacing $\psi/2$ with $-\psi/2$.

Next, to obtain the values of θ' , Figure A-3 is again used to note that the cosine law applied in triangle PQR' yields

$$\cos \psi/2 = \cos \phi \cos \phi' + \sin \phi \sin \phi' \cos (\theta' - \theta)$$

or (A-14)

$$\cos (\theta' - \theta) = (\cos \psi/2 - \cos \phi \cos \phi')/\sin \phi \sin \phi'$$

Since θ and all other quantities in Equation (A-14) are previously known through Equations (A-9), it remains only to obtain an independent relation for $\sin (\theta' - \theta)$ to uniquely specify the quadrant of θ' . The sine law applied to triangle PQR' yields

$$\frac{\sin \beta}{\sin \phi'} = \frac{\sin (\theta' - \theta)}{\sin \psi/2}$$

or (A-15)

$$\sin (\theta' - \theta) = \sin \beta \sin \psi/2/\sin \phi'$$

To obtain $\sin \beta$, it should be noted that, by definition,

$$\beta = 270^{\circ} - A$$

Therefore,

$$\sin \beta = \sin (270^{\circ} - A) = \sin (270^{\circ}) \cos A - \cos (270^{\circ}) \sin A$$
$$= -\cos A \qquad \text{(A-16)}$$

Applying the cosine law for angles to triangle PQS ,

$$\cos A = -\cos (90^{\circ} - i) \cos (\theta - \Omega) + \sin (90^{\circ} - i) \sin (\theta - \Omega) \cos (90^{\circ})$$
$$= -\sin i \cos (\theta - \Omega) \qquad \text{(A-17)}$$

However, the cosine law for sides in triangle PQS yields

$$\cos (\omega + f) = \cos (90^{\circ}) \cos \phi + \sin (90^{\circ}) \sin \phi \cos (\theta - \Omega)$$

or

$$\cos (\theta - \Omega) = \cos (\omega + f)/\sin \phi$$

Therefore, Equation (A-17) becomes

$$\cos A = -\sin i \cos (\omega + f)/\sin \phi \qquad \text{(A-18)}$$

Substituting Equation (A-18) into Equation (A-16), and then substituting the result into Equation (A-15) yields

$$\sin (\theta' - \theta) = \cos (\omega + f) \sin i \sin \psi/2/\sin \phi \sin \phi' \qquad \text{(A-19)}$$

Equations (A-14) and (A-19) are the desired expressions that uniquely determine θ' from previously known quantities. Alternative forms for Equation (A-19) were found, but the one given here offers the simplest functions

of the quantities, all of which are previously known and is the most rapid to compute, since no additional evaluations of trigonometric functions are required.

Again, by appropriately redrawing Figure A-3 and repeating the above analysis, it can be readily seen that Equations (A-14) and (A-19) uniquely yield θ' for the datum point corresponding to $-\psi/2$ on the other half of the scan arc. This is accomplished by entering Equations (A-19) with $-\psi/2$, and entering both Equations (A-14) and (A-19) with the appropriate ϕ' from Equation (A-13).

The important results just derived are Equations (A-13), (A-14) and (A-19), which yield ϕ' and θ' for pairs of datum points on any scan arc, and are cited as Equations (3-4), (3-5), (3-6), respectively, in the text. Caution is necessary when applying Equations (A-14) and (A-19) near the poles, since these relations are singular for subsatellite points or datum points at the poles. This is expected, since the geocentric longitudes θ and θ' are undefined at the poles. No problem need arise in computations, however, since the satellites are not expected to have exactly 90-degree inclinations and since, for the case of an equatorial orientation of the data base cube, it is a simple matter to regard the cube face coordinates of such datum points as zero within an arbitrary, but nonzero, distance from the poles.

APPENDIX B - BEST VALUES FOR THE COEFFICIENTS OF f*

For the form of the inverse mapping function, f* , given in Equation (3-42) the best derived coefficients are

$\gamma^* = 1.3682$	6932	2362
$\Gamma = -0.1268$	8142	8338
$M = -0.0024$	3108	1471
$\Omega_1 = -0.1583$	3565	5509
$C_{00} = 0.1014$	5485	8689
$C_{10} = 0.0160$	1398	7763
$C_{01} = -0.0904$	3332	1481
$C_{11} = 0.0574$	8768	5173
$C_{20} = -0.0272$	7606	9952
$C_{02} = -0.0342$	1969	6290
$D_0 = 0.0292$	5271	6867
$D_1 = 0.0059$	2537	5028

APPENDIX C - REFINEMENT OF THE CARTESIAN TRANSFORMATION

Section 3.3 of the text presented a numerically efficient and compact algorithm for employing the Cartesian transformation, f^*, defined in Section 2.2 to obtain the data base coordinates (x, y) of any datum point or pair of datum points on the (spherical) Earth's surface. This Appendix discusses the rationale for the new algorithms and provides a derivation of Equation (3-42).

C.1 OVERVIEW

The algorithm presented in Reference 1 (Section 4, Appendix B) already provides the essential information needed to implement f^*, but this study has found that the algorithm may be made more efficient computationally and better suited to computer programming by the following modifications:

- Take advantage of the nondimensional analysis presented in Appendix A that removes the need to compute the three-dimensional spatial coordinates of datum points by relying on simple direction cosines (l, m, n) of the subsatellite point and on the longitudes and colatitudes of the datum points.
- Allow for the Earth's rotation by using a varying node (see Appendix A) in computing the direction cosines instead of performing a separate transformation.
- Reduce by about half the computations required in cases of nonzero scan angles by viewing the scan arc as a central angle ψ_o (see Appendix A) and computing the data base coordinates for points in symmetrically placed pairs instead of treating each datum point independently.
- Remove a step from the algorithm, saving computations as well as yielding desirable numerical properties (see Section 3.4), by

introducing a change of variable that leads to a new formulation of f^*. The results of this step are summarized in Equations (3-40), (3-41), and (3-42) of Section 3.3.1. The mathematical details are presented in Section C.2 below.

C.2 REFORMULATION OF f^*

Table 3-2 (Section 3.3.1) establishes the conventions that define variables ξ', η', and ρ. These variables also appear in Table 4-1 of Reference 1, differing only in that l, m, and n are dimensionless (see Appendix A), whereas a, b, and c (of Reference 1) are spatial coordinates. Mathematically, ξ', η', and ρ behave identically here and in Reference 1.

In Reference 1, once ξ', η', ρ are found in Table 4-1, they are transformed to (ξ, η) by

$$\begin{aligned} \xi &= \xi' P \\ \eta &= \eta' P \end{aligned} \qquad \text{(C-1)}$$

where $P = r_o/\rho$ and $r_o = 1/\sqrt{3}$. The new variables ξ and η are then used in f^* to obtain the data base coordinates (x, y) by

$$\begin{aligned} x &= f^*(\xi,\eta) \\ y &= f^*(\eta,\xi) \end{aligned} \qquad \text{(C-2)}$$

The transformation given by Equations (C-1) can be eliminated by defining new variables α and β by

$$\begin{aligned} \alpha &= \xi'/\rho \\ \beta &= \eta'/\rho \end{aligned} \qquad \text{(C-3)}$$

Comparison of Equations (C-1) and (C-3) shows that the new variables α and β eliminate the computation of the intermediate quantity P and reduce the transformation to simple ratios of previously known quantities. The introduction of α and β will now be completed by deriving $f^*(\alpha, \beta)$, the transformed equivalent of $f^*(\xi, \eta)$, which was given in Section 2.2 and Reference 1 as

$$f^*(\xi,\eta) = \gamma^*\xi + \frac{1-\gamma^*}{r_o^2}\xi^3 + \xi\eta^2\left(r_o^2 - \xi^2\right)\left[\delta^* + \delta_1^*\left(r_o^2 - \xi^2\right)\right.$$

$$\left. + \left(r_o^2 - \eta^2\right)\sum_{\substack{i\geq 0\\ j\geq 0}} c_{ij}^*\,\xi^{2i}\,\eta^{2j}\right]$$

$$+ \xi^3\left(r_o^2 - \xi^2\right)\left[\omega^* + \left(r_o^2 - \xi^2\right)\sum_{i\geq 0} d_i^*\,\xi^{2i}\right]$$

where $r_o = 1/\sqrt{3}$ and

$$\gamma^* = \frac{1}{\gamma} \qquad \delta^* = \frac{(\mu_1^* - \mu^*)}{2r_o^4}$$

$$\mu^* = \frac{1}{\mu} \qquad \omega^* = \frac{1}{2r_o^4}\left(3 - 2\gamma^* - \mu^* - 2r_o^4\,\delta^*\right) \qquad \text{(C-5)}$$

$$\gamma_1^* = \frac{1}{\gamma + r_o^4\delta}$$

$$\mu_1^* = \frac{1}{\mu + 2r_o^4\delta} \qquad \delta_1^* = \frac{1}{r_o^2}\left[\frac{(\gamma_1^* - \gamma^*)}{r_o^4} - \delta^*\right]$$

and γ, μ, δ, ω, and the c_{ij}^* and d_i^* have the numerical values given in Section 2.2.

First, Equation (C-4) is expressed in terms of ξ', η', and ρ by using Equations (C-1)

$$
\begin{aligned}
f^*(\xi', \eta', \rho) = {} & \gamma^* r_o \, \xi'/\rho + \frac{1-\gamma^*}{r_o^2} \, r_o^3 \, (\xi'/\rho)^3 \\
& + r_o^3 \, (\xi' \, \eta'^2/\rho^3) \left[r_o^2 - r_o^2 \, (\xi'/\rho)^2 \right] \Bigg\{ \delta^* + \delta_1^* \left[r_o^2 - r_o^2 \, (\xi'/\rho)^2 \right] \\
& + \left[r_o^2 - r_o^2 \, (\eta'/\rho)^2 \right] \sum_{\substack{i \geq 0 \\ j \geq 0}} c_{ij}^* \, r_o^{2i+2j} \, (\xi'/\rho)^{2i} \, (\eta'/\rho)^{2j} \Bigg\} \qquad \text{(C-6)} \\
& + r_o^3 \, (\xi'/\rho)^3 \left[r_o^2 - r_o^2 \, (\xi'/\rho)^2 \right] \\
& \times \left\{ \omega^* + \left[r_o^2 - r_o^2 \, (\xi'/\rho)^2 \right] \sum_{i \geq 0} d_i^* \, r_o^{2i} \, (\xi'/\rho)^{2i} \right\}
\end{aligned}
$$

Next, α and β are introduced as defined in Equations (C-3), and powers of r_o are canceled in Equation (C-6), where appropriate, to obtain

$$
\begin{aligned}
f^*(\alpha, \beta) = {} & r_o \, \gamma^* \alpha + r_o \, (1-\gamma^*) \, \alpha^3 \\
& + \alpha \beta^2 \, (1-\alpha^2) \, r_o^5 \left[\delta^* + \delta_1^* \, r_o^2 \, (1-\alpha^2) \right. \\
& \left. + r_o^2 \, (1-\beta^2) \sum_{\substack{i \geq 0 \\ j \geq 0}} c_{ij}^* \, r_o^{2i+2j} \, \alpha^{2i} \, \beta^{2j} \right] \qquad \text{(C-7)} \\
& + \alpha^3 \, (1-\alpha^2) \, r_o^5 \left[\omega^* + r_o^2 \, (1-\alpha^2) \sum_{i \geq 0} d_i^* \, r_o^{2i} \, \alpha^{2i} \right]
\end{aligned}
$$

Equation (C-7) may be simplified ultimately by introducing the definitions (Equations (C-5)) of δ^*, ω^*, and δ_1^* to obtain:

$$
\begin{aligned}
f^*(\alpha, \beta) = {} & r_o \gamma^* \alpha + r_o (1 - \gamma^*) \alpha^3 + \alpha\beta^2 (1 - \alpha^2) r_o^5 \\
& \times \left[\frac{\mu_1^* - \mu^*}{2r_o^4} + \frac{r_o^2}{r_o^2} \left(\frac{\gamma_1^* - \gamma^*}{r_o^4} - \frac{\mu_1^* - \mu^*}{2r_o^4} \right) (1 - \alpha^2) \right. \\
& \left. + r_o^2 (1 - \beta^2) \sum_{\substack{i \geq 0 \\ j \geq 0}} c_{ij}^* r_o^{2i+2j} \alpha^{2i} \beta^{2j} \right] \\
& + \alpha^3 (1 - \alpha^2) r_o^5 \left\{ \frac{3 - 2\gamma^* - \mu^* - 2r_o^4 \left[(\mu_1^* - \mu^*)/2r_o^4 \right]}{2r_o^4} \right. \\
& \left. + r_o^2 (1 - \alpha^2) \sum_{i \geq 0} d_i^* r_o^{2i} \alpha^{2i} \right\}
\end{aligned}
\tag{C-8}
$$

Equation (C-8) is simplified by factoring the expression by r_o and carrying r_o^4 through the terms in box brackets to obtain

$$
\begin{aligned}
f^*(\alpha, \beta) = r_o \Bigg\{ & \gamma^* \alpha + (1 - \gamma^*) \alpha^3 + \alpha\beta^2 (1 - \alpha^2) \left[\frac{1}{2} (\mu_1^* - \mu^*) \right. \\
& \left. + \left(\gamma_1^* - \gamma^* - \frac{1}{2} (\mu_1^* - \mu^*) \right) (1 - \alpha^2) + (1 - \beta^2) \sum_{\substack{i \geq 0 \\ j \geq 0}} c_{ij}^* r_o^{2(i+j+3)} \alpha^{2i} \beta^{2j} \right] \\
& + \alpha^3 (1 - \alpha^2) \left[\frac{1}{2} (3 - 2\gamma^* - \mu^* + \mu^* - \mu_1^*) + (1 - \alpha^2) \right. \\
& \left. \times \sum_{i \geq 0} d_i^* r_o^{2(i+3)} \alpha^{2i} \right] \Bigg\}
\end{aligned}
\tag{C-9}
$$

Three new constants, M, Γ, and Ω_1, are introduced to replace δ^*, ω^*, and δ_1^* through the following definitions

$$M = \frac{1}{2}(\mu_1^* - \mu^*)$$

$$\Gamma = \gamma_1^* - \gamma^* \qquad \text{(C-10)}$$

$$\Omega_1 = \frac{1}{2}(3 - 2\gamma^* - \mu_1^*)$$

By comparing Equation (C-10) with Equation (C-5), it is seen that these new constants are considerably simpler in form.

Noting that r_o is strictly a constant, $r_o = 1/\sqrt{3}$, new coefficients C_{ij} and D_i are defined as follows

$$C_{ij} = c_{ij}^* \, r_o^{2(i+j+3)}$$

$$D_i = d_i^* \, r_o^{2(i+3)} \qquad \text{(C-11)}$$

Using Equations (C-10) and (C-11) in (C-9), the following is obtained

$$f^*(\alpha, \beta) = r_o \Bigg\{ \gamma^* \alpha + (1 - \gamma^*) \alpha^3 + \alpha\beta^2 (1 - \alpha^2)$$

$$\times \left[M + (\Gamma - M)(1 - \alpha^2) + (1 - \beta^2) \sum_{\substack{i \geq 0 \\ j \geq 0}} C_{ij} \alpha^{2i} \beta^{2j} \right] \qquad \text{(C-12)}$$

$$+ \alpha^3 (1 - \alpha^2) \left[\Omega_1 + (1 - \alpha^2) \sum_{i \geq 0} D_i \alpha^{2i} \right] \Bigg\}$$

This completes the derivation of the transformed expression for f^*. Equation (C-12) is given as Equation (3-42) in Section 3.3.1 and its numerical advantages are discussed in Section 3.5.

APPENDIX D - APPROXIMATION OF THE DIRECT AND INVERSE TRANSFORMATIONS

This appendix presents tables of coefficients for the approximate forms of the transformations f and f* as presented in Section 3.4. These tables are presented for one octant of one face. Each table contains 977 sets of coefficients (ordered by column), determined by using intersection points of a 32 x 32 triangular grid. Each set of coefficients represents the approximate form of the transformation within one element of the 32 x 32 grid. Each of these elements corresponds to one 64 x 64 element data face record at the 1.2 nautical mile scale.

Figure 3-13 illustrates the table octant (octant 1) and the seven other octants. Table D-1 is used to transform from (x, y) to (ξ, η) and Table D-2 is used to transform from (ξ, η) to (x, y). The steps outlined below are followed to transform from (x, y) to (ξ, η):

1. Add 2048.0 to x if x is less than 2048.0
2. Add 2048.0 to y if y is less than 2048.0
3. If y is greater than x, interchange x and y values
4. Truncate the x and y values obtained, divide each by 32, and add one, use these integers and IX and IY indices and look up the coefficients and number of terms in the table
5. Evaluate $f_a(x, y)$ to obtain ξ
6. Reverse steps 3, 2, and 1 to place ξ in its proper octant
7. Interchange x and y and repeat steps 2 through 7 to obtain η

Alternatively, steps 1, 2, 3, and 7 may be avoided by constructing a full 64 x 64 table containing redundant data.

Table D-1 (1 of 7)

IX		x_0	y_0	NTERMS	a_1	a_2	a_3	a_4	a_5	RESID.
1	1	2048.00	2048.00	2	0.7[illegible]	00 0.556605E-17	0.566567E 03	0.0	0.0	0.41504E-02
2	1	2112.00	2048.00	3	0.7[illegible]	00-0.119448E-09	0.566328E 03	0.0	0.0	0.10742E-01
2	2	2112.00	2112.00	3	0.7[illegible]	00-0.[illegible]	0.566337E 03	0.0	0.0	0.11719E-01
3	1	2176.00	2048.00	3	0.7[illegible]	00-0.267038E-04	0.555833E 03	0.0	0.0	0.17578E-01
3	2	2176.00	2112.00	3	0.7[illegible]	00-0.724208E-04	0.555844E 03	0.0	0.0	0.18799E-01
3	3	2176.00	2176.00	3	0.7[illegible]	00-0.114448E-03	0.555463E 03	0.0	0.0	0.19531E-01
4	1	2240.00	2048.00	3	0.7[illegible]	00-0.380878E-04	0.555761F 03	0.0	0.0	0.24658E-01
4	2	2240.00	2112.00	3	0.7[illegible]	00-0.114508E-03	0.555780E 03	0.0	0.0	0.25391E-01
4	3	2240.00	2176.00	3	0.7[illegible]	00-0.171668E-03	0.555102E 03	0.0	0.0	0.26367E-01
4	4	2240.00	2240.00	3	0.7[illegible]	00-0.214628E-03	0.555127E 03	0.0	0.0	0.27100E-01
5	1	2304.00	2048.00	3	0.7[illegible]	00-0.534006E-04	0.539996E 03	0.0	0.0	0.31250E-01
5	2	2304.00	2112.00	3	0.7[illegible]	00-0.152536E-03	0.540236E 03	0.0	0.0	0.32715E-01
5	3	2304.00	2176.00	3	0.7[illegible]	00-0.240276E-03	0.544636E 03	0.0	0.0	0.33936E-01
5	4	2304.00	2240.00	3	0.7[illegible]	00-0.[illegible]	0.540816E 03	0.0	0.0	0.34668E-01
5	5	2304.00	2304.00	3	0.7[illegible]	00-0.[illegible]	0.541066E 03	0.0	0.0	0.35156E-01
6	1	2368.00	2048.00	3	0.7[illegible]	00-0.[illegible]	0.526226E 03	0.0	0.0	0.38818E-01
6	2	2368.00	2112.00	3	0.7[illegible]	00-0.[illegible]	0.526546E 03	0.0	0.0	0.40039E-01
6	3	2368.00	2176.00	3	0.7[illegible]	00-0.[illegible]	0.526906E 03	0.0	0.0	0.41260E-01
6	4	2368.00	2240.00	3	0.7[illegible]	00-0.[illegible]	0.527276E 03	0.0	0.0	0.41748E-01
6	5	2368.00	2304.00	3	0.7[illegible]	00-0.[illegible]	0.527636E 03	0.0	0.0	0.42969E-01
6	6	2368.00	2368.00	3	0.7[illegible]	00-0.[illegible]	0.527746E 03	0.0	0.0	0.43213E-01
7	1	2432.00	2048.00	3	0.7[illegible]	00-0.[illegible]	0.509116E 03	0.0	0.0	0.46143E-01
7	2	2432.00	2112.00	3	0.7[illegible]	00-0.[illegible]	0.509536E 03	0.0	0.0	0.47119E-01
7	3	2432.00	2176.00	3	0.7[illegible]	00-0.[illegible]	0.507966E 03	0.0	0.0	0.48584E-01
7	4	2432.00	2240.00	3	0.7[illegible]	00-0.[illegible]	0.510346E 03	0.0	0.0	0.49805E-01
7	5	2432.00	2304.00	3	0.7[illegible]	00-0.[illegible]	0.510756E 03	0.0	0.0	0.50781E-01
7	6	2432.00	2368.00	3	0.7[illegible]	00-0.[illegible]	0.510976E 03	0.0	0.0	0.51270E-01
7	7	2432.00	2432.00	3	0.7[illegible]	00-0.[illegible]	0.510986E 03	0.0	0.0	0.51270E-01
8	1	2496.00	2048.00	3	0.7[illegible]	00-0.[illegible]	0.488446E 03	0.0	0.0	0.52979E-01
8	2	2496.00	2112.00	3	0.7[illegible]	00-0.[illegible]	0.488916E 03	0.0	0.0	0.54932E-01
8	3	2496.00	2176.00	3	0.7[illegible]	00-0.[illegible]	0.489436E 03	0.0	0.0	0.56396E-01
8	4	2496.00	2240.00	3	0.7[illegible]	00-0.[illegible]	0.489966E 03	0.0	0.0	0.57861E-01
8	5	2496.00	2304.00	3	0.7[illegible]	00-0.[illegible]	0.490386E 03	0.0	0.0	0.59326E-01
8	6	2496.00	2368.00	3	0.7[illegible]	00-0.[illegible]	0.490686E 03	0.0	0.0	0.59819E-01
8	7	2496.00	2432.00	3	0.7[illegible]	00-0.[illegible]	0.490726E 03	0.0	0.0	0.60547E-01
8	8	2496.00	2496.00	3	0.7[illegible]	00-0.[illegible]	0.490456E 03	0.0	0.0	0.60059E-01
9	1	2560.00	2048.00	3	0.7[illegible]	00-0.[illegible]	0.468886E 03	0.0	0.0	0.61038E-01
9	2	2560.00	2112.00	3	0.7[illegible]	00-0.[illegible]	0.469456E 03	0.0	0.0	0.62988E-01
9	3	2560.00	2176.00	3	0.7[illegible]	00-0.[illegible]	0.469076E 03	0.0	0.0	0.64941E-01
9	4	2560.00	2240.00	3	0.7[illegible]	00-0.[illegible]	0.469876E 03	0.0	0.0	0.66406E-01
9	5	2560.00	2304.00	3	0.7[illegible]	00-0.[illegible]	0.466246E 03	0.0	0.0	0.67627E-01
9	6	2560.00	2368.00	3	0.7[illegible]	00-0.[illegible]	0.466576E 03	0.0	0.0	0.68092E-01
9	7	2560.00	2432.00	3	0.7[illegible]	00-0.[illegible]	0.466726E 03	0.0	0.0	0.69336E-01
9	8	2560.00	2496.00	3	0.7[illegible]	00-0.[illegible]	0.466456E 03	0.0	0.0	0.70068E-01
9	9	2560.00	2560.00	3	0.7[illegible]	00-0.[illegible]	0.466746E 03	0.0	0.0	0.69893E-01
10	1	2624.00	2048.00	3	0.7[illegible]	00-0.[illegible]	0.435156E 03	0.0	0.0	0.69336E-01
10	2	2624.00	2112.00	3	0.7[illegible]	00-0.[illegible]	0.435826E 03	0.0	0.0	0.71533E-01
10	3	2624.00	2176.00	3	0.7[illegible]	00-0.[illegible]	0.436586E 03	0.0	0.0	0.72754E-01
10	4	2624.00	2240.00	3	0.7[illegible]	00-0.[illegible]	0.437296E 03	0.0	0.0	0.74707E-01
10	5	2624.00	2304.00	3	0.7[illegible]	00-0.[illegible]	0.437956E 03	0.0	0.0	0.76416E-01
10	6	2624.00	2368.00	3	0.7[illegible]	00-0.[illegible]	0.438426E 03	0.0	0.0	0.78125E-01
10	7	2624.00	2432.00	3	0.7[illegible]	00-0.[illegible]	0.438606E 03	0.0	0.0	0.78613E-01

Table D-1 (2 of 7)

10	8	2624.00	2496.00	3	0.776066E	00-0.514926-03	0.43863E 03	0.0	0.0	0.793406-01
10	9	2624.00	2560.00	3	0.775866E	00-0.267036-04	0.43772E 03	0.0	0.0	0.793406-01
10	10	2624.00	2624.00	3	0.775676E	00 0.648446-03	0.43644E 03	0.0	0.0	0.788876-01
11	1	2688.00	2048.00	3	0.789446E	00-0.179236-03	0.40194E 03	0.0	0.0	0.778816-01
11	2	2688.00	2112.00	3	0.789426E	00-0.511116-03	0.40068E 03	0.0	0.0	0.778436-01
11	3	2688.00	2176.00	3	0.789236E	00-0.757276-03	0.40351E 03	0.0	0.0	0.822786-01
11	4	2688.00	2240.00	3	0.788216E	00-0.102616-02	0.40839E 03	0.0	0.0	0.844236-01
11	5	2688.00	2304.00	3	0.786946E	00-0.115586-02	0.40514E 03	0.0	0.0	0.844206-01
11	6	2688.00	2368.00	3	0.788836E	00-0.116356-02	0.40573E 03	0.0	0.0	0.883796-01
11	7	2688.00	2432.00	3	0.790596E	00-0.102996-02	0.40809E 03	0.0	0.0	0.888476-01
11	8	2688.00	2496.00	3	0.788346E	00-0.729986-03	0.40594E 03	0.0	0.0	0.899446-01
11	9	2688.00	2560.00	3	0.785096E	00-0.209816-03	0.40530E 03	0.0	0.0	0.905706-01
11	10	2688.00	2624.00	3	0.781806E	00 0.514026-03	0.40403E 03	0.0	0.0	0.900886-01
11	11	2688.00	2688.00	3	0.781676E	00 0.144026-02	0.40195E 03	0.0	0.0	0.894006-01
12	1	2752.00	2048.00	3	0.803136E	00-0.158306-03	0.38372E 03	0.0	0.0	0.868146-01
12	2	2752.00	2112.00	3	0.803116E	00-0.567406-03	0.36462E 03	0.0	0.0	0.893896-01
12	3	2752.00	2176.00	3	0.803226E	00-0.923796-03	0.36561E 03	0.0	0.0	0.915636-01
12	4	2752.00	2240.00	3	0.803096E	00-0.119796-02	0.36649E 03	0.0	0.0	0.930046-01
12	5	2752.00	2304.00	3	0.802896E	00-0.136576-02	0.36749E 03	0.0	0.0	0.940916-01
12	6	2752.00	2368.00	3	0.802666E	00-0.140376-02	0.36823E 03	0.0	0.0	0.970396-01
12	7	2752.00	2432.00	3	0.802406E	00-0.127616-02	0.36984E 03	0.0	0.0	0.990896-01
12	8	2752.00	2496.00	3	0.802116E	00-0.972756-03	0.36884E 03	0.0	0.0	0.100346 00
12	9	2752.00	2560.00	3	0.801816E	00-0.642456-03	0.36809E 03	0.0	0.0	0.101566 00
12	10	2752.00	2624.00	3	0.801556E	00 0.324256-03	0.36685E 03	0.0	0.0	0.101816 00
12	11	2752.00	2688.00	3	0.801296E	00 0.134286-02	0.36483E 03	0.0	0.0	0.101566 00
12	12	2752.00	2752.00	3	0.801046E	00 0.246276-02	0.36178E 03	0.0	0.0	0.101076 00
13	1	2816.00	2048.00	3	0.819636E	00-0.225136-03	0.32014E 03	0.0	0.0	0.971606-01
13	2	2816.00	2112.00	3	0.819796E	00-0.675146-03	0.32120E 03	0.0	0.0	0.980776-01
13	3	2816.00	2176.00	3	0.819706E	00-0.116816-02	0.32231E 03	0.0	0.0	0.101566 00
13	4	2816.00	2240.00	3	0.819556E	00-0.135856-02	0.32345E 03	0.0	0.0	0.104006 00
13	5	2816.00	2304.00	3	0.819356E	00-0.159636-02	0.32450E 03	0.0	0.0	0.106456 00
13	6	2816.00	2368.00	3	0.819106E	00-0.166706-02	0.32537E 03	0.0	0.0	0.108156 00
13	7	2816.00	2432.00	3	0.818826E	00-0.156026-02	0.32591E 03	0.0	0.0	0.110356 00
13	8	2816.00	2496.00	3	0.818506E	00-0.125606-02	0.32603E 03	0.0	0.0	0.112806 00
13	9	2816.00	2560.00	3	0.817176E	00-0.729056-03	0.32560E 03	0.0	0.0	0.113286 00
13	10	2816.00	2624.00	3	0.816986E	00 0.610616-04	0.32447E 03	0.0	0.0	0.113776 00
13	11	2816.00	2688.00	3	0.816536E	00 0.114446-02	0.32295E 03	0.0	0.0	0.114756 00
13	12	2816.00	2752.00	3	0.816246E	00 0.251776-02	0.31947E 03	0.0	0.0	0.114016 00
13	13	2816.00	2816.00	3	0.815626E	00 0.422676-02	0.31529E 03	0.0	0.0	0.112506 00
14	1	2880.00	2048.00	3	0.836026E	00-0.263206-03	0.27073E 03	0.0	0.0	0.106456 00
14	2	2880.00	2112.00	3	0.836036E	00-0.766756-03	0.27186E 03	0.0	0.0	0.109426 00
14	3	2880.00	2176.00	3	0.835936E	00-0.121066-02	0.27313E 03	0.0	0.0	0.112806 00
14	4	2880.00	2240.00	3	0.835736E	00-0.159076-02	0.27444E 03	0.0	0.0	0.114756 00
14	5	2880.00	2304.00	3	0.835516E	00-0.165016-02	0.27564E 03	0.0	0.0	0.116946 00
14	6	2880.00	2368.00	3	0.835256E	00-0.194936-02	0.27655E 03	0.0	0.0	0.120126 00
14	7	2880.00	2432.00	3	0.834946E	00-0.187686-02	0.27736E 03	0.0	0.0	0.122316 00
14	8	2880.00	2496.00	3	0.834546E	00-0.158696-02	0.27784E 03	0.0	0.0	0.125026 00
14	9	2880.00	2560.00	3	0.834226E	00-0.104906-02	0.27733E 03	0.0	0.0	0.125736 00
14	10	2880.00	2624.00	3	0.833996E	00-0.251736-03	0.27633E 03	0.0	0.0	0.127206 00
14	11	2880.00	2688.00	3	0.833496E	00 0.894356-03	0.27441E 03	0.0	0.0	0.127936 00
14	12	2880.00	2752.00	3	0.833136E	00 0.229276-02	0.27145E 03	0.0	0.0	0.127936 00
14	13	2880.00	2816.00	3	0.832436E	00 0.4Cd18E-02	0.26729E 03	0.0	0.0	0.127696 00
14	14	2880.00	2880.00	3	0.832576E	00 0.629236-02	0.26173E 03	0.0	0.0	0.126776 00
15	1	2944.00	2048.00	3	0.855596E	00-0.289916-03	0.21475E 03	0.0	0.0	0.110416 00
15	2	2944.00	2112.00	3	0.855016E	00-0.865936-03	0.21609E 03	0.0	0.0	0.120816 00
15	3	2944.00	2176.00	3	0.854916E	00-0.138046-02	0.21751E 03	0.0	0.0	0.122806 00
15	4	2944.00	2240.00	3	0.854746E	00-0.180446-02	0.21894E 03	0.0	0.0	0.125906 00
15	5	2944.00	2304.00	3	0.854546E	00-0.211336-02	0.22033E 03	0.0	0.0	0.128446 00
15	6	2944.00	2368.00	3	0.854236E	00-0.226596-02	0.22152E 03	0.0	0.0	0.131846 00
15	7	2944.00	2432.00	3	0.853906E	00-0.222026-02	0.22239E 03	0.0	0.0	0.134036 00
15	8	2944.00	2496.00	3	0.853536E	00-0.195696-02	0.22282E 03	0.0	0.0	0.136726 00
15	9	2944.00	2560.00	3	0.853116E	00-0.142676-02	0.22264E 03	0.0	0.0	0.138026 00
15	10	2944.00	2624.00	3	0.852706E	00-0.621796-03	0.22178E 03	0.0	0.0	0.140186 00
15	11	2944.00	2688.00	3	0.852286E	00 0.514986-03	0.21997E 03	0.0	0.0	0.142096 00
15	12	2944.00	2752.00	3	0.851866E	00 0.199136-02	0.21714E 03	0.0	0.0	0.143076 00
15	13	2944.00	2816.00	3	0.851446E	00 0.383746-02	0.21304E 03	0.0	0.0	0.142686 00
15	14	2944.00	2880.00	3	0.851146E	00 0.668446-02	0.20761E 03	0.0	0.0	0.142586 00
15	15	2944.00	2944.00	3	0.850876E	00 0.876206-02	0.20052E 03	0.0	0.0	0.141116 00
16	1	3008.00	2048.00	3	0.876036E	00-0.331896-03	0.15172E 03	0.0	0.0	0.124896 00
16	2	3008.00	2112.00	3	0.876006E	00-0.765136-03	0.15318E 03	0.0	0.0	0.132326 00
16	3	3008.00	2176.00	3	0.875906E	00-0.154506-02	0.15473E 03	0.0	0.0	0.139816 00
16	4	3008.00	2240.00	3	0.875726E	00-0.203716-02	0.15635E 03	0.0	0.0	0.138186 00
16	5	3008.00	2304.00	3	0.875496E	00-0.239566-02	0.15790E 03	0.0	0.0	0.141306 00
16	6	3008.00	2368.00	3	0.875196E	00-0.249706-02	0.15905E 03	0.0	0.0	0.144046 00
16	7	3008.00	2432.00	3	0.874856E	00-0.259026-02	0.16028E 03	0.0	0.0	0.146976 00
16	8	3008.00	2496.00	3	0.874456E	00-0.235756-02	0.16089E 03	0.0	0.0	0.150156 00
16	9	3008.00	2560.00	3	0.874026E	00-0.185016-02	0.16090E 03	0.0	0.0	0.152006 00
16	10	3008.00	2624.00	3	0.873566E	00-0.104526-02	0.16017E 03	0.0	0.0	0.154306 00
16	11	3008.00	2688.00	3	0.873096E	00 0.451756-04	0.15850E 03	0.0	0.0	0.156006 00
16	12	3008.00	2752.00	3	0.872616E	00 0.159836-02	0.15581E 03	0.0	0.0	0.156206 00
16	13	3008.00	2816.00	3	0.872156E	00 0.350196-02	0.15184E 03	0.0	0.0	0.159186 00

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21	5	3328.00	2304.00	3	0.101666	01	-0.387586	-02	-0.29204E	03	0.0	0.0	0.21882E 00
21	6	3328.00	2368.00	3	0.101646	01	-0.43679E	-02	-0.29000E	03	0.0	0.0	0.22095E 00
21	7	3328.00	2432.00	3	0.101605	01	-0.46387E	-02	-0.28828E	03	0.0	0.0	0.22363E 00
21	8	3328.00	2496.00	3	0.101575	01	-0.48463E	-02	-0.28703E	03	0.0	0.0	0.22778E 00
21	9	3328.00	2560.00	3	0.101526	01	-0.43450E	-02	-0.28638E	03	0.0	0.0	0.23389E 00
21	10	3328.00	2624.00	3	0.101478	01	-0.37079E	-02	-0.28640E	03	0.0	0.0	0.23755E 00
21	11	3328.00	2688.00	3	0.101422	01	-0.27006E	-02	-0.28726E	03	0.0	0.0	0.24369E 00
21	12	3328.00	2752.00	3	0.101368	01	-0.12817E	-02	-0.28910E	03	0.0	0.0	0.24731E 00
21	13	3328.00	2816.00	3	0.101296	01	0.57980E	-03	-0.29209E	03	0.0	0.0	0.25122E 00
21	14	3328.00	2880.00	3	0.101225	01	0.29335E	-02	-0.29642E	03	0.0	0.0	0.25659E 00
21	15	3328.00	2944.00	3	0.101145	01	0.57869E	-02	-0.30218E	03	0.0	0.0	0.26099E 00
21	16	3328.00	3008.00	3	0.101065	01	0.91857E	-02	-0.30954E	03	0.0	0.0	0.26465E 00
21	17	3328.00	3072.00	3	0.100965	01	0.13134E	-01	-0.31864E	03	0.0	0.0	0.26978E 00
21	18	3328.00	3136.00	3	0.100836	01	0.17673E	-01	-0.32966E	03	0.0	0.0	0.27515E 00
21	19	3328.00	3200.00	3	0.100706	01	0.22831E	-01	-0.34285E	03	0.0	0.0	0.28181E 00
21	20	3328.00	3264.00	3	0.100565	01	0.28580E	-01	-0.35809E	03	0.0	0.0	0.28125E 00
21	21	3328.00	3328.00	3	0.100556	01	0.34973E	-01	-0.37580E	03	0.0	0.0	0.28369E 00
22	1	3392.00	2240.00	3	0.105425	01	-0.59266E	-03	-0.42696E	03	0.0	0.0	0.22510E 00
22	2	3392.00	2112.00	3	0.105426	01	-0.15041E	-02	-0.42468E	03	0.0	0.0	0.22944E 00
22	3	3392.00	2176.00	3	0.105411	01	-0.25330E	-02	-0.42234E	03	0.0	0.0	0.23047E 00
22	4	3392.00	2240.00	3	0.105403	01	-0.34066E	-02	-0.41997E	03	0.0	0.0	0.21482E 00
22	5	3392.00	2304.00	3	0.105397	01	-0.41389E	-02	-0.41772E	03	0.0	0.0	0.23560E 00
22	6	3392.00	2368.00	3	0.105337	01	-0.48845E	-02	-0.41567E	03	0.0	0.0	0.23779E 00
22	7	3392.00	2432.00	3	0.105336	01	-0.56038E	-02	-0.41388E	03	0.0	0.0	0.24243E 00
22	8	3392.00	2496.00	3	0.105308	01	-0.63735E	-02	-0.41271E	03	0.0	0.0	0.24878E 00
22	9	3392.00	2560.00	3	0.105265	01	-0.70408E	-02	-0.41199E	03	0.0	0.0	0.25024E 00
22	10	3392.00	2624.00	3	0.105228	01	-0.42686E	-02	-0.41197E	03	0.0	0.0	0.25708E 00
22	11	3392.00	2688.00	3	0.105177	01	-0.13187E	-02	-0.41274E	03	0.0	0.0	0.26270E 00
22	12	3392.00	2752.00	3	0.105117	01	0.19608E	-02	-0.41448E	03	0.0	0.0	0.26782E 00
22	13	3392.00	2816.00	3	0.105049	01	0.15259E	-03	-0.41733E	03	0.0	0.0	0.27319E 00
22	14	3392.00	2880.00	3	0.104971	01	0.21400E	-02	-0.42141E	03	0.0	0.0	0.28181E 00
22	15	3392.00	2944.00	3	0.104867	01	0.45285E	-02	-0.42679E	03	0.0	0.0	0.28504E 00
22	16	3392.00	3008.00	3	0.104705	01	0.82740E	-02	-0.43376E	03	0.0	0.0	0.29199E 00
22	17	3392.00	3072.00	3	0.104496	01	0.12109E	-01	-0.44233E	03	0.0	0.0	0.29976E 00
22	18	3392.00	3136.00	3	0.104259	01	0.16072E	-01	-0.45277E	03	0.0	0.0	0.30371E 00
22	19	3392.00	3200.00	3	0.103946	01	0.21770E	-01	-0.46500E	03	0.0	0.0	0.31055E 00
22	20	3392.00	3264.00	3	0.103434	01	0.27750E	-01	-0.47944E	03	0.0	0.0	0.31616E 00
22	21	3392.00	3328.00	3	0.103295	01	0.33474E	-01	-0.49598E	03	0.0	0.0	0.31934E 00
22	22	3392.00	3392.00	3	0.103065	01	0.40878E	-01	-0.51488E	03	0.0	0.0	0.32282E 00
23	1	3456.00	2944.00	3	0.107554	01	-0.54936E	-03	-0.56835E	03	0.0	0.0	0.25220E 00
23	2	3456.00	2112.00	3	0.107541	01	-0.14327E	-02	-0.56600E	03	0.0	0.0	0.25293E 00
23	3	3456.00	2176.00	3	0.107491	01	-0.28551E	-02	-0.56354E	03	0.0	0.0	0.25480E 00
23	4	3456.00	2240.00	3	0.107403	01	-0.35744E	-02	-0.56126E	03	0.0	0.0	0.25806E 00
23	5	3456.00	2304.00	3	0.107337	01	-0.41564E	-02	-0.55901E	03	0.0	0.0	0.25903E 00
23	6	3456.00	2368.00	3	0.107247	01	-0.45953E	-02	-0.55703E	03	0.0	0.0	0.26318E 00
23	7	3456.00	2432.00	3	0.107145	01	-0.53306E	-02	-0.55539E	03	0.0	0.0	0.26489E 00
23	8	3456.00	2496.00	3	0.107024	01	-0.54588E	-02	-0.55415E	03	0.0	0.0	0.26855E 00
23	9	3456.00	2560.00	3	0.106890	01	-0.52810E	-02	-0.55346E	03	0.0	0.0	0.27417E 00
23	10	3456.00	2624.00	3	0.106753	01	-0.47815E	-02	-0.55346E	03	0.0	0.0	0.27979E 00
23	11	3456.00	2688.00	3	0.106615	01	-0.39063E	-02	-0.55427E	03	0.0	0.0	0.28540E 00
23	12	3456.00	2752.00	3	0.106469	01	-0.26207E	-02	-0.55597E	03	0.0	0.0	0.29395E 00
23	13	3456.00	2816.00	3	0.106317	01	-0.90027E	-03	-0.55862E	03	0.0	0.0	0.30029E 00
23	14	3456.00	2880.00	3	0.106139	01	0.13084E	-02	-0.56245E	03	0.0	0.0	0.30396E 00
23	15	3456.00	2944.00	3	0.105904	01	0.40164E	-02	-0.56757E	03	0.0	0.0	0.31396E 00
23	16	3456.00	3008.00	3	0.105584	01	0.72708E	-02	-0.57408E	03	0.0	0.0	0.32831E 00
23	17	3456.00	3072.00	3	0.105053	01	0.11076E	-01	-0.58205E	03	0.0	0.0	0.32739E 00
23	18	3456.00	3136.00	3	0.104711	01	0.15489E	-01	-0.59172E	03	0.0	0.0	0.33390E 00
23	19	3456.00	3200.00	3	0.104056	01	0.20504E	-01	-0.60315E	03	0.0	0.0	0.34379E 00
23	20	3456.00	3264.00	3	0.103436	01	0.26136E	-01	-0.61635E	03	0.0	0.0	0.35034E 00
23	21	3456.00	3328.00	3	0.103265	01	0.32421E	-01	-0.63157E	03	0.0	0.0	0.35815E 00
23	22	3456.00	3392.00	3	0.104654	01	0.39349E	-01	-0.64886E	03	0.0	0.0	0.36570E 00
23	23	3456.00	3456.00	3	0.107698	01	0.46925E	-01	-0.66824E	03	0.0	0.0	0.37354E 00
24	1	3520.00	2048.00	3	0.114036	01	-0.56885E	-01	-0.72719E	01	0.0	0.0	0.27412E 00
24	2	3520.00	2112.00	3	0.114039	01	-0.16861E	-02	-0.72482E	03	0.0	0.0	0.27563E 00
24	3	3520.00	2176.00	3	0.114036	01	-0.27351E	-02	-0.72247E	03	0.0	0.0	0.28101E 00
24	4	3520.00	2240.00	3	0.114026	01	-0.37033E	-02	-0.72013E	03	0.0	0.0	0.28294E 00
24	5	3520.00	2304.00	3	0.114021	01	-0.45204E	-02	-0.71802E	03	0.0	0.0	0.28369E 00
24	6	3520.00	2368.00	3	0.114011	01	-0.51651E	-02	-0.71616E	03	0.0	0.0	0.28760E 00
24	7	3520.00	2432.00	3	0.113991	01	-0.58038E	-02	-0.71454E	03	0.0	0.0	0.29199E 00
24	8	3520.00	2496.00	3	0.113988	01	-0.57793E	-02	-0.71358E	03	0.0	0.0	0.29370E 00
24	9	3520.00	2560.00	3	0.113956	01	-0.56763E	-02	-0.71303E	03	0.0	0.0	0.29880E 00
24	10	3520.00	2624.00	3	0.113942	01	-0.52452E	-02	-0.71314E	03	0.0	0.0	0.30420E 00
24	11	3520.00	2688.00	3	0.113896	01	-0.44403E	-02	-0.71404E	03	0.0	0.0	0.31095E 00
24	12	3520.00	2752.00	3	0.113804	01	-0.32540E	-02	-0.71560E	03	0.0	0.0	0.31610E 00
24	13	3520.00	2816.00	3	0.113798	01	-0.16251E	-02	-0.71832E	03	0.0	0.0	0.32397E 00
24	14	3520.00	2880.00	3	0.113725	01	0.47678E	-03	-0.72203E	03	0.0	0.0	0.33288E 00
24	15	3520.00	2944.00	3	0.113642	01	0.30708E	-02	-0.72684E	03	0.0	0.0	0.34131E 00
24	16	3520.00	3008.00	3	0.113545	01	0.61913E	-02	-0.73288E	03	0.0	0.0	0.35107E 00
24	17	3520.00	3072.00	3	0.113438	01	0.98801E	-02	-0.74036E	03	0.0	0.0	0.36084E 00
24	18	3520.00	3136.00	3	0.113308	01	0.14137E	-01	-0.74909E	03	0.0	0.0	0.37158E 00

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24	19	3520.00	3200.00	3	0.11316E	01	0.19005E-01	-0.75944E	03	0.0	0.0	0.37744E	00
24	20	3520.00	3264.00	3	0.11349E	01	0.24490E-01	-0.77136E	03	0.0	0.0	0.38574E	00
24	21	3520.00	3328.00	3	0.11379E	01	0.30021E-01	-0.78501E	03	0.0	0.0	0.40039E	00
24	22	3520.00	3392.00	3	0.11405E	01	0.37384E-01	-0.80036E	03	0.0	0.0	0.41994E	00
24	23	3520.00	3456.00	3	0.11424E	01	0.44811E-01	-0.81759E	03	0.0	0.0	0.41992E	00
24	24	3520.00	3520.00	3	0.11437E	01	0.52866E-01	-0.83660E	03	0.0	0.0	0.42627E	00
25	1	3584.00	2048.00	3	0.11391E	01	0.57222E-03	-0.90628E	03	0.0	0.0	0.30103E	00
25	2	3584.00	2112.00	3	0.11431E	01	-0.17052E-02	-0.90391E	03	0.0	0.0	0.30811E	00
25	3	3584.00	2176.00	3	0.11903E	01	-0.27847E-02	-0.90156E	03	0.0	0.0	0.30518E	00
25	4	3584.00	2240.00	3	0.11903E	01	-0.37652E-02	-0.89941E	03	0.0	0.0	0.30746E	00
25	5	3584.00	2304.00	3	0.11901E	01	-0.46120E-02	-0.89746E	03	0.0	0.0	0.31177E	00
25	6	3584.00	2368.00	3	0.11903E	01	-0.52987E-02	-0.89583E	03	0.0	0.0	0.31228E	00
25	7	3584.00	2432.00	3	0.11911E	01	-0.57755E-02	-0.89457E	03	0.0	0.0	0.31731E	00
25	8	3584.00	2496.00	3	0.11902E	01	-0.60120E-02	-0.89376E	03	0.0	0.0	0.31738E	00
25	9	3584.00	2560.00	3	0.11901E	01	-0.59866E-02	-0.89350E	03	0.0	0.0	0.32326E	00
25	10	3584.00	2624.00	3	0.11899E	01	-0.56070E-02	-0.89384E	03	0.0	0.0	0.32939E	00
25	11	3584.00	2688.00	3	0.11897E	01	-0.48981E-02	-0.89484E	03	0.0	0.0	0.33179E	00
25	12	3584.00	2752.00	3	0.11894E	01	-0.38078E-02	-0.89654E	03	0.0	0.0	0.34184E	00
25	13	3584.00	2816.00	3	0.11888E	01	-0.22926E-02	-0.89939E	03	0.0	0.0	0.35059E	00
25	14	3584.00	2880.00	3	0.11881E	01	-0.12812E-03	-0.90295E	03	0.0	0.0	0.36133E	00
25	15	3584.00	2944.00	3	0.11876E	01	0.21210E-02	-0.90751E	03	0.0	0.0	0.36885E	00
25	16	3584.00	3008.00	3	0.11867E	01	0.56811E-02	-0.91311E	03	0.0	0.0	0.37891E	00
25	17	3584.00	3072.00	3	0.11857E	01	0.85810E-02	-0.91984E	03	0.0	0.0	0.39087E	00
25	18	3584.00	3136.00	3	0.11842E	01	0.12653E-01	-0.92778E	03	0.0	0.0	0.40259E	00
25	19	3584.00	3200.00	3	0.11826E	01	0.17303E-01	-0.93693E	03	0.0	0.0	0.41479E	00
25	20	3584.00	3264.00	3	0.11807E	01	0.22578E-01	-0.94741E	03	0.0	0.0	0.42334E	00
25	21	3584.00	3328.00	3	0.11786E	01	0.28665E-01	-0.95923E	03	0.0	0.0	0.44238E	00
25	22	3584.00	3392.00	3	0.11760E	01	0.34985E-01	-0.97236E	03	0.0	0.0	0.45306E	00
25	23	3584.00	3456.00	3	0.11732E	01	0.42156E-01	-0.98699E	03	0.0	0.0	0.46831E	00
25	24	3584.00	3520.00	3	0.11700E	01	0.49457E-01	-0.10030E	04	0.0	0.0	0.48389E	00
25	25	3584.00	3584.00	3	0.11664E	01	0.56807E-01	-0.10204E	04	0.0	0.0	0.49585E	00
26	1	3648.00	2048.00	3	0.12457E	01	-0.76834E-03	-0.11086E	04	0.0	0.0	0.34058E	00
26	2	3648.00	2112.00	3	0.12457E	01	-0.17052E-02	-0.11062E	04	0.0	0.0	0.34326E	00
26	3	3648.00	2176.00	3	0.12454E	01	-0.27733E-02	-0.11041E	04	0.0	0.0	0.33667E	00
26	4	3648.00	2240.00	3	0.12449E	01	-0.37614E-02	-0.11021E	04	0.0	0.0	0.34058E	00
26	5	3648.00	2304.00	3	0.12445E	01	-0.46159E-02	-0.11005E	04	0.0	0.0	0.34180E	00
26	6	3648.00	2368.00	3	0.12440E	01	-0.53254E-02	-0.10992E	04	0.0	0.0	0.34424E	00
26	7	3648.00	2432.00	3	0.12441E	01	-0.58365E-02	-0.10983E	04	0.0	0.0	0.34717E	00
26	8	3648.00	2496.00	3	0.12442E	01	-0.61183E-02	-0.10979E	04	0.0	0.0	0.35181E	00
26	9	3648.00	2560.00	3	0.12445E	01	-0.61303E-02	-0.10981E	04	0.0	0.0	0.35571E	00
26	10	3648.00	2624.00	3	0.12451E	01	-0.58480E-02	-0.10988E	04	0.0	0.0	0.35620E	00
26	11	3648.00	2688.00	3	0.12460E	01	-0.52334E-02	-0.11002E	04	0.0	0.0	0.36743E	00
26	12	3648.00	2752.00	3	0.12469E	01	-0.42457E-02	-0.11023E	04	0.0	0.0	0.37109E	00
26	13	3648.00	2816.00	3	0.12479E	01	-0.28763E-02	-0.11051E	04	0.0	0.0	0.38574E	00
26	14	3648.00	2880.00	3	0.12485E	01	-0.10682E-02	-0.11086E	04	0.0	0.0	0.39233E	00
26	15	3648.00	2944.00	3	0.12484E	01	0.12016E-02	-0.11130E	04	0.0	0.0	0.40186E	00
26	16	3648.00	3008.00	3	0.12481E	01	0.39558E-02	-0.11182E	04	0.0	0.0	0.41357E	00
26	17	3648.00	3072.00	3	0.12477E	01	0.72364E-02	-0.11243E	04	0.0	0.0	0.42603E	00
26	18	3648.00	3136.00	3	0.12474E	01	0.11055E-01	-0.11313E	04	0.0	0.0	0.43823E	00
26	19	3648.00	3200.00	3	0.12469E	01	0.15427E-01	-0.11392E	04	0.0	0.0	0.44140E	00
26	20	3648.00	3264.00	3	0.12463E	01	0.20405E-01	-0.11480E	04	0.0	0.0	0.47461E	00
26	21	3648.00	3328.00	3	0.12452E	01	0.25959E-01	-0.11576E	04	0.0	0.0	0.49072E	00
26	22	3648.00	3392.00	3	0.12434E	01	0.32150E-01	-0.11683E	04	0.0	0.0	0.50700E	00
26	23	3648.00	3456.00	3	0.12391E	01	0.38948E-01	-0.11798E	04	0.0	0.0	0.52393E	00
26	24	3648.00	3520.00	3	0.12253E	01	0.46381E-01	-0.11921E	04	0.0	0.0	0.54344E	00
26	25	3648.00	3584.00	3	0.12211E	01	0.54424E-01	-0.12055E	04	0.0	0.0	0.55859E	00
26	26	3648.00	3648.00	3	0.12162E	01	0.63095E-01	-0.12195E	04	0.0	0.0	0.58203E	00
27	1	3712.00	2048.00	3	0.13079E	01	-0.99314E-03	-0.13380E	04	0.0	0.0	0.37042E	00
27	2	3712.00	2112.00	3	0.13076E	01	-0.16595E-02	-0.13358E	04	0.0	0.0	0.38257E	00
27	3	3712.00	2176.00	3	0.13077E	01	-0.27008E-02	-0.13339E	04	0.0	0.0	0.37793E	00
27	4	3712.00	2240.00	3	0.13076E	01	-0.36698E-02	-0.13323E	04	0.0	0.0	0.37939E	00
27	5	3712.00	2304.00	3	0.13078E	01	-0.45205E-02	-0.13311E	04	0.0	0.0	0.38550E	00
27	6	3712.00	2368.00	3	0.13082E	01	-0.52261E-02	-0.13303E	04	0.0	0.0	0.38281E	00
27	7	3712.00	2432.00	3	0.13085E	01	-0.57450E-02	-0.13300E	04	0.0	0.0	0.38354E	00
27	8	3712.00	2496.00	3	0.13086E	01	-0.60654E-02	-0.13301E	04	0.0	0.0	0.38843E	00
27	9	3712.00	2560.00	3	0.13090E	01	-0.61268E-02	-0.13304E	04	0.0	0.0	0.39043E	00
27	10	3712.00	2624.00	3	0.13092E	01	-0.59280E-02	-0.13322E	04	0.0	0.0	0.39744E	00
27	11	3712.00	2688.00	3	0.13091E	01	-0.54054E-02	-0.13341E	04	0.0	0.0	0.40405E	00
27	12	3712.00	2752.00	3	0.13094E	01	-0.45434E-02	-0.13368E	04	0.0	0.0	0.41284E	00
27	13	3712.00	2816.00	3	0.13094E	01	-0.33227E-02	-0.13397E	04	0.0	0.0	0.41528E	00
27	14	3712.00	2880.00	3	0.13090E	01	-0.17014E-02	-0.13433E	04	0.0	0.0	0.42884E	00
27	15	3712.00	2944.00	3	0.13085E	01	0.35858E-03	-0.13477E	04	0.0	0.0	0.43884E	00
27	16	3712.00	3008.00	3	0.13078E	01	0.28687E-02	-0.13525E	04	0.0	0.0	0.45479E	00
27	17	3712.00	3072.00	3	0.13068E	01	0.50669E-02	-0.13580E	04	0.0	0.0	0.47102E	00
27	18	3712.00	3136.00	3	0.13055E	01	0.93688E-02	-0.13639E	04	0.0	0.0	0.48057E	00
27	19	3712.00	3200.00	3	0.13037E	01	0.13397E-01	-0.13704E	04	0.0	0.0	0.50439E	00
27	20	3712.00	3264.00	3	0.13016E	01	0.17979E-01	-0.13774E	04	0.0	0.0	0.52171E	00
27	21	3712.00	3328.00	3	0.12989E	01	0.23132E-01	-0.13848E	04	0.0	0.0	0.54541E	00
27	22	3712.00	3392.00	3	0.12958E	01	0.28870E-01	-0.13925E	04	0.0	0.0	0.56201E	00
27	23	3712.00	3456.00	3	0.12920E	01	0.35183E-01	-0.14005E	04	0.0	0.0	0.58765E	00

27	24	3712.00	3320.00	1	0.12[illegible]	01	0.42095E-01-0.14086E 04	0.0	0.0	0.[illegible] 00
27	25	3712.00	3344.00	1	0.12[illegible]	01	0.41614E-01-0.14178E 04	0.0	0.0	0.[illegible] 00
27	26	3712.00	3648.00	1	0.12[illegible]	01	0.57705E-01-0.14253E 04	0.0	0.0	0.65771E 00
27	27	3712.00	3712.00	1	0.12[illegible]	01	0.66391E-01-0.14336E 04	0.0	0.0	0.67[illegible] 00
28	1	3776.00	2048.00	1	0.13[illegible]	01	-0.52273E-03-0.15[illegible] 04	0.0	0.0	0.43[illegible] 00
28	2	3776.00	2112.00	1	0.13[illegible]	01	-0.15605E-02-0.15976E 04	0.0	0.0	0.42749E 00
28	3	3776.00	2176.00	1	0.13[illegible]	01	-0.25485E-02-0.15980E 04	0.0	0.0	0.42773E 00
28	4	3776.00	2240.00	1	0.13[illegible]	01	-0.34716E-02-0.15949E 04	0.0	0.0	0.43237E 00
28	5	3776.00	2304.00	1	0.13[illegible]	01	-0.42878E-02-0.15942E 04	0.0	0.0	0.43164E 00
28	6	3776.00	2368.00	1	0.13[illegible]	01	-0.49638E-02-0.15942E 04	0.0	0.0	0.43140E 00
28	7	3776.00	2432.00	1	0.13[illegible]	01	-0.54895E-02-0.15946E 04	0.0	0.0	0.43091E 00
28	8	3776.00	2496.00	1	0.13[illegible]	01	-0.58138E-02-0.15956E 04	0.0	0.0	0.43774E 00
28	9	3776.00	2560.00	1	0.13[illegible]	01	-0.59282E-02-0.15971E 04	0.0	0.0	0.44169E 00
28	10	3776.00	2624.00	1	0.13[illegible]	01	-0.57873E-02-0.15992E 04	0.0	0.0	0.44482E 00
28	11	3776.00	2688.00	1	0.13[illegible]	01	-0.53713E-02-0.16018E 04	0.0	0.0	0.44822E 00
28	12	3776.00	2752.00	1	0.13[illegible]	01	-0.46464E-02-0.16049E 04	0.0	0.0	0.45381E 00
28	13	3776.00	2816.00	1	0.13[illegible]	01	-0.35936E-02-0.16084E 04	0.0	0.0	0.46313E 00
28	14	3776.00	2880.00	1	0.13[illegible]	01	-0.21[illegible] 04	0.0	0.0	0.47461E 00
28	15	3776.00	2944.00	1	0.13[illegible]	01	-0.36246E-03-0.16168E 04	0.0	0.0	0.48975E 00
28	16	3776.00	3008.00	1	0.13[illegible]	01	0.16539E-02-0.16213E 04	0.0	0.0	0.50342E 00
28	17	3776.00	3072.00	1	0.14[illegible]	01	0.45128E-02-0.16262E 04	0.0	0.0	0.51020E 00
28	18	3776.00	3136.00	1	0.14[illegible]	01	0.76407E-02-0.16312E 04	0.0	0.0	0.54004E 00
28	19	3776.00	3200.00	1	0.14[illegible]	01	0.11[illegible] 04	0.0	0.0	0.55688E 00
28	20	3776.00	3264.00	1	0.13[illegible]	01	0.15350E-01-0.16411E 04	0.0	0.0	0.58618E 00
28	21	3776.00	3328.00	1	0.13[illegible]	01	0.18974E-01-0.16458E 04	0.0	0.0	0.60693E 00
28	22	3776.00	3392.00	1	0.13[illegible]	01	0.25[illegible] 04	0.0	0.0	0.63066E 00
28	23	3776.00	3456.00	1	0.13[illegible]	01	0.30634E-01-0.16541E 04	0.0	0.0	0.65918E 00
28	24	3776.00	3520.00	1	0.13[illegible]	01	0.37086E-01-0.16575E 04	0.0	0.0	0.68774E 00
28	25	3776.00	3584.00	1	0.13[illegible]	01	0.43900E-01-0.16601E 04	0.0	0.0	0.71729E 00
28	26	3776.00	3648.00	1	0.14[illegible]	01	0.51447E-01-0.16618E 04	0.0	0.0	0.74878E 00
28	27	3776.00	3712.00	1	0.14[illegible]	01	0.59155E-01-0.16624E 04	0.0	0.0	0.77710E 00
28	28	3776.00	3776.00	1	0.13[illegible]	01	0.67577E-01-0.16617E 04	0.0	0.0	0.81470E 00
29	1	3840.00	2048.00	1	0.14[illegible]	01	-0.47690E-03-0.18993E 04	0.0	0.0	0.49219E 00
29	2	3840.00	2112.00	1	0.14[illegible]	01	-0.14077E-02-0.18976E 04	0.0	0.0	0.48901E 00
29	3	3840.00	2176.00	1	0.14[illegible]	01	-0.23041E-02-0.18965E 04	0.0	0.0	0.48950E 00
29	4	3840.00	2240.00	1	0.14[illegible]	01	-0.31397E-02-0.18960E 04	0.0	0.0	0.48413E 00
29	5	3840.00	2304.00	1	0.14[illegible]	01	-0.38835E-02-0.18962E 04	0.0	0.0	0.48755E 00
29	6	3840.00	2368.00	1	0.14[illegible]	01	-0.45129E-02-0.18970E 04	0.0	0.0	0.48755E 00
29	7	3840.00	2432.00	1	0.14[illegible]	01	-0.50[illegible] 04	0.0	0.0	0.49268E 00
29	8	3840.00	2496.00	1	0.14[illegible]	01	-0.54307E-02-0.19004E 04	0.0	0.0	0.49512E 00
29	9	3840.00	2560.00	1	0.14[illegible]	01	-0.54706E-02-0.19030E 04	0.0	0.0	0.49341E 00
29	10	3840.00	2624.00	1	0.14[illegible]	01	-0.53[illegible] 04	0.0	0.0	0.50090E 00
29	11	3840.00	2688.00	1	0.14[illegible]	01	-0.50737E-02-0.19097E 04	0.0	0.0	0.50562E 00
29	12	3840.00	2752.00	1	0.14[illegible]	01	-0.44[illegible] 04	0.0	0.0	0.50537E 00
29	13	3840.00	2816.00	1	0.14[illegible]	01	-0.36204E-02-0.19179E 04	0.0	0.0	0.51782E 00
29	14	3840.00	2880.00	1	0.14[illegible]	01	-0.24339E-02-0.19223E 04	0.0	0.0	0.52344E 00
29	15	3840.00	2944.00	1	0.14[illegible]	01	-0.[illegible] 04	0.0	0.0	0.53931E 00
29	16	3840.00	3008.00	1	0.14[illegible]	01	-0.67257E-03-0.19313E 04	0.0	0.0	0.55347E 00
29	17	3840.00	3072.00	1	0.14[illegible]	01	0.32384E-02-0.19356E 04	0.0	0.0	0.57178E 00
29	18	3840.00	3136.00	1	0.14[illegible]	01	0.68[illegible] 04	0.0	0.0	0.59619E 00
29	19	3840.00	3200.00	1	0.14[illegible]	01	0.89[illegible] 04	0.0	0.0	0.62109E 00
29	20	3840.00	3264.00	1	0.14[illegible]	01	0.12527E-01-0.19456E 04	0.0	0.0	0.64575E 00
29	21	3840.00	3328.00	1	0.14[illegible]	01	0.16502E-01-0.19474E 04	0.0	0.0	0.68018E 00
29	22	3840.00	3392.00	1	0.14[illegible]	01	0.20[illegible] 04	0.0	0.0	0.71265E 00
29	23	3840.00	3456.00	1	0.14[illegible]	01	0.25894E-01-0.19474E 04	0.0	0.0	0.73999E 00
29	24	3840.00	3520.00	1	0.14[illegible]	01	0.31[illegible] 04	0.0	0.0	0.77197E 00
29	25	3840.00	3584.00	1	0.14[illegible]	01	0.37239E-01-0.19413E 04	0.0	0.0	0.80804E 00
29	26	3840.00	3648.00	1	0.14[illegible]	01	0.43[illegible] 04	0.0	0.0	0.84429E 00
29	27	3840.00	3712.00	1	0.14[illegible]	01	0.50533E-01-0.19269E 04	0.0	0.0	0.88843E 00
29	28	3840.00	3776.00	1	0.14[illegible]	01	0.57903E-01-0.19159E 04	0.0	0.0	0.93115E 00
29	29	3840.00	3840.00	1	0.13[illegible]	01	0.65750E-01-0.19021E 04	0.0	0.0	0.98558E 00
30	1	3904.00	2048.00	1	0.15[illegible]	01	-0.40436E-03-0.22450E 04	0.0	0.0	0.55981E 00
30	2	3904.00	2112.00	1	0.15[illegible]	01	-0.11402E-02-0.22438E 04	0.0	0.0	0.56006E 00
30	3	3904.00	2176.00	1	0.15[illegible]	01	-0.15494E-02-0.22433E 04	0.0	0.0	0.55420E 00
30	4	3904.00	2240.00	1	0.15[illegible]	01	-0.26553E-02-0.22436E 04	0.0	0.0	0.55518E 00
30	5	3904.00	2304.00	1	0.15[illegible]	01	-0.33[illegible] 04	0.0	0.0	0.55444E 00
30	6	3904.00	2368.00	1	0.15[illegible]	01	-0.3E378E-02-0.22467E 04	0.0	0.0	0.55420E 00
30	7	3904.00	2432.00	1	0.15[illegible]	01	-0.42689E-02-0.22493E 04	0.0	0.0	0.55591E 00
30	8	3904.00	2496.00	1	0.15[illegible]	01	-0.45703E-02-0.22526E 04	0.0	0.0	0.56421E 00
30	9	3904.00	2560.00	1	0.15[illegible]	01	-0.47113E-02-0.22566E 04	0.0	0.0	0.56787E 00
30	10	3904.00	2624.00	1	0.15[illegible]	01	-0.46847E-02-0.22610E 04	0.0	0.0	0.56152E 00
30	11	3904.00	2688.00	1	0.15[illegible]	01	-0.44634E-02-0.22658E 04	0.0	0.0	0.57422E 00
30	12	3904.00	2752.00	1	0.15[illegible]	01	-0.40209E-02-0.22710E 04	0.0	0.0	0.57568E 00
30	13	3904.00	2816.00	1	0.15[illegible]	01	-0.33[illegible] 04	0.0	0.0	0.57903E 00
30	14	3904.00	2880.00	1	0.15[illegible]	01	-0.24262E-02-0.22813E 04	0.0	0.0	0.59229E 00
30	15	3904.00	2944.00	1	0.15[illegible]	01	-0.12246E-02-0.22863E 04	0.0	0.0	0.59912E 00
30	16	3904.00	3008.00	1	0.15[illegible]	01	0.27835E-03-0.22908E 04	0.0	0.0	0.61548E 00
30	17	3904.00	3072.00	1	0.15[illegible]	01	0.20753E-02-0.22946E 04	0.0	0.0	0.64160E 00
30	18	3904.00	3136.00	1	0.15[illegible]	01	0.42154E-02-0.22975E 04	0.0	0.0	0.66[illegible] 00
30	19	3904.00	3200.00	1	0.15[illegible]	01	0.66[illegible] 04	0.0	0.0	0.68[illegible] 00

Table D-1 (7 of 7)

30	20	3904.00	3264.00	1	0.154855	01	0.33406E-02	-0.22995E	04	0.0		0.0		0.72021E	00
30	21	3904.00	3328.00	3	0.154545	01	0.32753E-01	-0.22980E	04	0.0		0.0		0.74434E	00
30	22	3904.00	3392.00	3	0.154145	01	0.16350E-01	-0.22946E	04	0.0		0.0		0.79156E	00
30	23	3904.00	3456.00	3	0.153644	01	0.20351E-01	-0.22887E	04	0.0		0.0		0.82910E	00
30	24	3904.00	3520.00	3	0.153027	01	0.24785E-01	-0.22802E	04	0.0		0.0		0.87009E	00
30	25	3904.00	3584.00	3	0.152294	01	0.25568E-01	-0.22686E	04	0.0		0.0		0.91309E	00
30	26	3904.00	3648.00	3	0.151415	01	0.34801E-01	-0.22537E	04	0.0		0.0		0.96285E	00
30	27	3904.00	3712.00	4	-0.149356E-03		0.21853E	01	0.75702E	00	-0.48949E	04	0.0		0.59351E	00
30	28	3904.00	3776.00	4	-0.204546E-03		0.32797E	01	0.86041E	00	-0.52864E	04	0.0		0.58740E	00
30	29	3904.00	3840.00	4	-0.236625E-03		0.30375E	01	0.97669E	00	-0.57320E	04	0.0		0.57600E	00
30	30	3904.00	3904.00	4	-0.26541E-01		0.25000E	01	0.10959E	01	-0.61975E	04	0.0		0.56299E	00
31	1	3968.00	2048.00	3	0.154456	01	-0.10547E-03		0.26467E	04	0.0		0.0		0.64367E	00
31	2	3968.00	2112.00	3	0.154026	01	-0.88519E-03		0.26460E	04	0.0		0.0		0.64185E	00
31	3	3968.00	2176.00	3	0.153497	01	-0.14613E-02		0.26463E	04	0.0		0.0		0.63905E	00
31	4	3968.00	2240.00	3	0.152876	01	-0.19054E-02		0.26476E	04	0.0		0.0		0.63802E	00
31	5	3968.00	2304.00	3	0.152169	01	-0.24759E-02		0.26500E	04	0.0		0.0		0.63698E	00
31	6	3968.00	2368.00	3	0.151379	01	-0.28881E-02		0.26533E	04	0.0		0.0		0.63501E	00
31	7	3968.00	2432.00	3	0.150509	01	-0.32273E-02		0.26576E	04	0.0		0.0		0.63294E	00
31	8	3968.00	2496.00	3	0.149558	01	-0.34594E-02		0.26625E	04	0.0		0.0		0.64185E	00
31	9	3968.00	2560.00	3	0.148518	01	-0.35932E-02		0.26681E	04	0.0		0.0		0.64355E	00
31	10	3968.00	2624.00	3	0.147413	01	-0.36019E-02		0.26742E	04	0.0		0.0		0.64589E	00
31	11	3968.00	2688.00	3	0.146247	01	-0.36037E-02		0.26807E	04	0.0		0.0		0.65430E	00
31	12	3968.00	2752.00	3	0.145031	01	-0.31061E-02		0.26873E	04	0.0		0.0		0.65669E	00
31	13	3968.00	2816.00	3	0.143774	01	-0.27122E-02		0.26938E	04	0.0		0.0		0.66113E	00
31	14	3968.00	2880.00	3	0.142487	01	-0.27114E-02		0.26999E	04	0.0		0.0		0.67139E	00
31	15	3968.00	2944.00	3	0.141196	01	-0.24086E-02		0.27056E	04	0.0		0.0		0.68116E	00
31	16	3968.00	3008.00	3	0.139909	01	-0.17172E-03		0.27102E	04	0.0		0.0		0.69253E	00
31	17	3968.00	3072.00	3	0.138645	01	0.11023E-02		0.27136E	04	0.0		0.0		0.71940E	00
31	18	3968.00	3136.00	3	0.137408	01	0.26321E-02		0.27156E	04	0.0		0.0		0.76300E	00
31	19	3968.00	3200.00	3	0.136218	01	0.43907E-02		0.27156E	04	0.0		0.0		0.77580E	00
31	20	3968.00	3264.00	3	0.135090	01	0.54241E-02		0.27132E	04	0.0		0.0		0.80737E	00
31	21	3968.00	3328.00	3	0.134024	01	0.47260E-02		0.27082E	04	0.0		0.0		0.85205E	00
31	22	3968.00	3392.00	3	0.133047	01	0.11318E-01		0.27001E	04	0.0		0.0		0.88721E	00
31	23	3968.00	3456.00	3	0.132424	01	0.14194E-01		0.26864E	04	0.0		0.0		0.93530E	00
31	24	3968.00	3520.00	3	0.131857	01	0.17172E-01		0.26727E	04	0.0		0.0		0.98462E	00
31	25	3968.00	3584.00	4	-0.135394E-03		0.63129E	01	0.63129E	00	-0.48403E	04	0.0		0.69312E	00
31	26	3968.00	3648.00	4	-0.143965E-03		0.52759E	01	0.74065E	00	-0.52394E	04	0.0		0.68311E	00
31	27	3968.00	3712.00	4	-0.150495E-01		0.43892E	01	0.86595E	00	-0.57043E	04	0.0		0.66895E	00
31	28	3968.00	3776.00	4	-0.144284E-03		0.25009E	01	0.99363E	00	-0.61857E	04	0.0		0.66479E	00
31	29	3968.00	3840.00	4	-0.127187E-01		0.26338E	01	0.11290E	01	-0.67092E	04	0.0		0.65723E	00
31	30	3968.00	3904.00	4	-0.109951E-01		0.27581E	01	0.12711E	01	-0.72617E	04	0.0		0.64063E	00
31	31	3968.00	3968.00	4	-0.447344E-03		0.25183E	01	0.14206E	01	-0.74784E	04	0.0		0.63206E	00
32	1	4032.00	2048.00	3	0.177191	01	-0.16415E-03		0.31166E	04	0.0		0.0		0.75415E	00
32	2	4032.00	2112.00	3	0.176811	01	-0.53422E-03		0.31165E	04	0.0		0.0		0.74650E	00
32	3	4032.00	2176.00	3	0.176315	01	-0.41646E-03		0.31179E	04	0.0		0.0		0.74048E	00
32	4	4032.00	2240.00	3	0.175725	01	-0.11178E-02		0.31205E	04	0.0		0.0		0.74121E	00
32	5	4032.00	2304.00	3	0.175056	01	-0.13026E-02		0.31244E	04	0.0		0.0		0.74023E	00
32	6	4032.00	2368.00	3	0.174308	01	-0.16251E-02		0.31295E	04	0.0		0.0		0.74023E	00
32	7	4032.00	2432.00	3	0.173495	01	-0.18235E-02		0.31355E	04	0.0		0.0		0.74316E	00
32	8	4032.00	2496.00	3	0.172644	01	-0.19606E-02		0.31425E	04	0.0		0.0		0.74779E	00
32	9	4032.00	2560.00	3	0.171764	01	-0.20485E-02		0.31502E	04	0.0		0.0		0.74487E	00
32	10	4032.00	2624.00	3	0.170864	01	-0.20601E-02		0.31585E	04	0.0		0.0		0.74390E	00
32	11	4032.00	2688.00	3	0.169952	01	-0.20028E-02		0.31669E	04	0.0		0.0		0.75000E	00
32	12	4032.00	2752.00	3	0.169036	01	-0.18577E-02		0.31754E	04	0.0		0.0		0.75195E	00
32	13	4032.00	2816.00	3	0.168123	01	-0.16250E-02		0.31835E	04	0.0		0.0		0.75977E	00
32	14	4032.00	2880.00	3	0.167220	01	-0.12895E-02		0.31911E	04	0.0		0.0		0.77026E	00
32	15	4032.00	2944.00	3	0.166334	01	-0.86866E-03		0.31976E	04	0.0		0.0		0.77905E	00
32	16	4032.00	3008.00	3	0.165471	01	-0.24806E-03		0.32036E	04	0.0		0.0		0.78057E	00
32	17	4032.00	3072.00	3	0.164634	01	0.36898E-03		0.32059E	04	0.0		0.0		0.81152E	00
32	18	4032.00	3136.00	3	0.163829	01	0.11977E-02		0.32069E	04	0.0		0.0		0.84229E	00
32	19	4032.00	3200.00	3	0.163058	01	0.21398E-02		0.32051E	04	0.0		0.0		0.87793E	00
32	20	4032.00	3264.00	3	0.162327	01	0.32111E-02		0.32000E	04	0.0		0.0		0.91650E	00
32	21	4032.00	3328.00	3	0.161642	01	0.44671E-02		0.31911E	04	0.0		0.0		0.95828E	00
32	22	4032.00	3392.00	4	-0.211288E-04		0.26801E	01	0.37329E	00	-0.44241E	04	0.0		0.79932E	00
32	23	4032.00	3456.00	4	-0.116215E-01		0.21567E	01	0.47599E	00	-0.47789E	04	0.0		0.79408E	00
32	24	4032.00	3520.00	4	-0.142337E-01		0.22587E	01	0.58300E	00	-0.51567E	04	0.0		0.78370E	00
32	25	4032.00	3584.00	4	-0.171667E-03		0.23638E	01	0.70313E	00	-0.55861E	04	0.0		0.78320E	00
32	26	4032.00	3648.00	4	-0.204618E-01		0.24840E	01	0.83805E	00	-0.60782E	04	0.0		0.77856E	00
32	27	4032.00	3712.00	4	-0.239415E-01		0.26132E	01	0.98059E	00	-0.66074E	04	0.0		0.76993E	00
32	28	4032.00	3776.00	4	-0.276976E-01		0.27550E	01	0.11345E	01	-0.71885E	04	0.0		0.76488E	00
32	29	4032.00	3840.00	4	-0.315968E-01		0.29086E	01	0.12982E	01	-0.78175E	04	0.0		0.76409E	00
32	30	4032.00	3904.00	4	-0.357965E-03		0.30753E	01	0.14731E	01	-0.85003E	04	0.0		0.76285E	00
32	31	4032.00	3968.00	4	-0.404826E-03		0.32546E	01	0.16581E	01	-0.92346E	04	0.0		0.76028E	00
32	32	4032.00	4032.00	4	-0.456187E-03		0.34443E	01	0.18508E	01	-0.10012E	05	0.0		0.48306E	00

IEF142I - STEP WAS EXECUTED - COND CODE 0000
IEF285I SYS1.DUMMY KEPT
IEF285I VOL SER NOS= M2D9M1.

Table D–2 (1 of 7)

IP	IE	x_0	y_0	NTERMS	a_1	a_2	a_3	a_4	a_5	RESID.
1	1	2048.00	2304.00	3	0.11742E 01	-0.99405E-07	-0.75840E 03	0.0	0.0	0.14893E-01
1	1	2112.00	2304.00	4	0.11707E 01	0.75533E-05	-0.75955E 03	0.0	0.0	0.36377E-01
1	2	2112.00	2112.00	3	0.11707E 01	0.22388E-04	-0.75395E 03	0.0	0.0	0.37842E-01
1	1	2176.00	2048.00	3	0.11693E 01	0.16377E-04	-0.74344E 03	0.0	0.0	0.59082E-01
1	2	2176.00	2112.00	3	0.11674E 01	0.44934E-04	-0.74356E 03	0.0	0.0	0.59570E-01
1	3	2176.00	2176.00	3	0.11634E 01	0.70834E-04	-0.74369E 03	0.0	0.0	0.60888E-01
A	1	2240.00	2048.00	3	0.11730E 01	0.30458E-04	-0.71991E 03	0.0	0.0	0.78369E-01
A	2	2240.00	2112.00	4	0.11536E 01	0.83221E-04	-0.72305E 03	0.0	0.0	0.79834E-01
A	3	2240.00	2176.00	3	0.11571E 01	0.87[illegible]E-04	-0.72015E 03	0.0	0.0	0.80322E-01
A	4	2240.00	2240.00	3	0.11581E 01	0.25703E-04	-0.72016E 03	0.0	0.0	0.80811E-01
B	1	2304.00	2240.00	3	0.13256E 01	0.49531E-04	-0.69795E 03	0.0	0.0	0.95987E-01
B	2	2304.00	2112.00	3	0.13350E 01	0.12553E-03	-0.68917E 03	0.0	0.0	0.97412E-01
B	3	2304.00	2176.00	3	0.13330E 01	0.14496E-03	-0.69133E 03	0.0	0.0	0.98877E-01
B	4	2304.00	2304.00	3	0.13356E 01	0.34434E-04	-0.68833E 03	0.0	0.0	0.10084E 00
C	1	2368.00	2304.00	3	0.13354E 01	-0.12357E-03	-0.66802E 03	0.0	0.0	0.10254E 00
C	2	2368.00	2240.00	4	0.13320E 01	0.48565E-04	-0.64742E 03	0.0	0.0	0.11816E 00
C	3	2368.00	2112.00	4	0.13321E 01	0.17335E-03	-0.64775E 03	0.0	0.0	0.11987E 00
C	4	2368.00	2176.00	3	0.13321E 01	0.22507E-03	-0.64903E 03	0.0	0.0	0.12099E 00
C	5	2368.00	2240.00	3	0.13326E 01	0.15543E-03	-0.64911E 03	0.0	0.0	0.12036E 00
C	6	2368.00	2304.00	3	0.13326E 01	-0.68455E-04	-0.64791E 03	0.0	0.0	0.11987E 00
C	7	2368.00	2368.00	3	0.13326E 01	-0.48834E-03	-0.64715E 03	0.0	0.0	0.12134E 00
D	1	2432.00	2048.00	3	0.13814E 01	0.95182E-04	-0.60466E 03	0.0	0.0	0.13868E 00
D	2	2432.00	2112.00	3	0.13030E 01	0.25171E-03	-0.56710E 03	0.0	0.0	0.13696E 00
D	3	2432.00	2176.00	3	0.13021E 01	0.33194E-03	-0.59247E 03	0.0	0.0	0.13940E 00
D	4	2432.00	2240.00	4	0.13022E 01	0.27341E-03	-0.59963E 03	0.0	0.0	0.13989E 00
D	5	2432.00	2304.00	3	0.13023E 01	0.30459E-04	-0.59947E 03	0.0	0.0	0.14233E 00
D	6	2432.00	2368.00	3	0.13023E 01	-0.43492E-03	-0.59375E 03	0.0	0.0	0.14233E 00
D	7	2432.00	2432.00	3	0.13036E 01	-0.11713E-02	-0.59725E 03	0.0	0.0	0.14063E 00
E	1	2496.00	2048.00	3	0.12759E 01	0.12589E-03	-0.54148E 03	0.0	0.0	0.14941E 00
E	2	2496.00	2112.00	3	0.12761E 01	0.34333E-03	-0.54310E 03	0.0	0.0	0.15084E 00
E	3	2496.00	2176.00	3	0.12751E 01	0.46156E-03	-0.54255E 03	0.0	0.0	0.15771E 00
E	4	2496.00	2240.00	3	0.12753E 01	0.43499E-03	-0.54397E 03	0.0	0.0	0.15804E 00
E	5	2496.00	2304.00	4	0.12755E 01	0.19073E-03	-0.54292E 03	0.0	0.0	0.15790E 00
E	6	2496.00	2368.00	4	0.12757E 01	-0.31652E-03	-0.54214E 03	0.0	0.0	0.15991E 00
E	7	2496.00	2432.00	3	0.12800E 01	-0.11178E-02	-0.54085E 03	0.0	0.0	0.16016E 00
E	8	2496.00	2496.00	3	0.12801E 01	-0.22459E-02	-0.53529E 03	0.0	0.0	0.15804E 00
F	1	2560.00	2048.00	3	0.12136E 01	0.16785E-03	-0.47542E 03	0.0	0.0	0.16406E 00
F	2	2560.00	2112.00	3	0.12636E 01	0.44436E-03	-0.47708E 03	0.0	0.0	0.16846E 00
F	3	2560.00	2176.00	4	0.12537E 01	0.62343E-03	-0.47784E 03	0.0	0.0	0.17090E 00
F	4	2560.00	2240.00	3	0.12539E 01	0.64397E-03	-0.47d35E 03	0.0	0.0	0.17407E 00
F	5	2560.00	2304.00	4	0.12541E 01	0.40817E-03	-0.47839E 03	0.0	0.0	0.17554E 00
F	6	2560.00	2368.00	4	0.12544E 01	-0.11063E-03	-0.47791E 03	0.0	0.0	0.17871E 00
F	7	2560.00	2432.00	3	0.12547E 01	-0.98332E-03	-0.47449E 03	0.0	0.0	0.18066E 00
F	8	2560.00	2496.00	3	0.12550E 01	-0.82126E-02	-0.47411E 03	0.0	0.0	0.17822E 00
F	9	2560.00	2560.00	3	0.12551E 01	-0.38719E-02	-0.47322E 03	0.0	0.0	0.17749E 00
G	1	2624.00	2048.00	3	0.12267E 01	0.20490E-03	-0.40340E 03	0.0	0.0	0.17847E 00
G	2	2624.00	2112.00	4	0.12259E 01	0.57602E-03	-0.40446E 03	0.0	0.0	0.18091E 00
G	3	2624.00	2176.00	3	0.12260E 01	0.82397E-03	-0.40527E 03	0.0	0.0	0.18220E 00
G	4	2624.00	2240.00	3	0.12262E 01	0.78501E-03	-0.40609E 03	0.0	0.0	0.18403E 00
G	5	2624.00	2304.00	3	0.12264E 01	0.69046E-03	-0.40636E 03	0.0	0.0	0.18312E 00
G	6	2624.00	2368.00	3	0.12266E 01	0.17166E-03	-0.40605E 03	0.0	0.0	0.18807E 00
G	7	2624.00	2432.00	3	0.12271E 01	-0.72867E-03	-0.40478E 03	0.0	0.0	0.19400E 00
G	8	2624.00	2496.00	3	0.12275E 01	-0.20495E-02	-0.40245E 03	0.0	0.0	0.19504E 00
G	9	2624.00	2560.00	3	0.12278E 01	-0.38109E-03	-0.39869E 03	0.0	0.0	0.19405E 00
G	10	2624.00	2624.00	4	0.12290E 01	-0.60386E-02	-0.39339E 03	0.0	0.0	0.19116E 00
H	1	2688.00	2048.00	3	0.11959E 01	0.25177E-03	-0.32340E 03	0.0	0.0	0.18791E 00
H	2	2688.00	2112.00	3	0.11959E 01	0.71335E-03	-0.32448E 03	0.0	0.0	0.18948E 00
H	3	2688.00	2176.00	3	0.11961E 01	0.10567E-02	-0.32573E 03	0.0	0.0	0.19507E 00

Table D-2 (2 of 7)

Table D-2 (3 of 7)

17	4	3072.00	2247.30	1	0.291554E	00	0.355553E-02	0.265446E	03	0.0	0.0	0.226884E 00
17	5	3072.00	2304.00	1	0.291562E	00	0.350216E-02	0.261325E	03	0.0	0.0	0.232188E 00
17	6	3072.00	2349.00	1	0.293456E	00	0.390663E-02	0.261186E	03	0.0	0.0	0.240408E 00
17	7	3072.00	2432.00	1	0.293078E	00	0.374179E-02	0.261318E	03	0.0	0.0	0.247008E 00
17	8	3072.00	2466.00	1	0.293386E	00	0.388016E-02	0.261038E	03	0.0	0.0	0.254614E 00
17	9	3072.00	2560.00	1	0.294468E	00	0.450155E-03	0.263708E	03	0.0	0.0	0.268999E 00
17	10	3072.00	2654.00	1	0.295858E	00	0.195445E-02	0.267268E	03	0.0	0.0	0.271008E 00
17	11	3072.00	2697.00	1	0.296858E	00	0.301225E-02	0.272188E	03	0.0	0.0	0.276888E 00
17	12	3072.00	2752.00	1	0.297738E	00	0.470838E-02	0.278838E	03	0.0	0.0	0.284188E 00
17	13	3072.00	2816.00	1	0.298008E	00	0.513048E-02	0.286700E	03	0.0	0.0	0.288888E 00
17	14	3072.00	2880.00	1	0.300648E	01	0.117860E-01	0.295928E	03	0.0	0.0	0.296148E 00
17	15	3072.00	2944.00	1	0.300178E	01	0.231828E-01	0.308118E	03	0.0	0.0	0.299888E 00
17	16	3072.00	3008.00	1	0.300348E	01	0.304968E-01	0.320048E	03	0.0	0.0	0.302588E 00
17	17	3072.00	3072.00	1	0.300508E	01	0.364978E-01	0.333998E	03	0.0	0.0	0.303718E 00
18	1	3136.00	2048.00	1	0.385448E	00	0.675208E-03	0.384688E	03	0.0	0.0	0.206548E 00
18	2	3136.00	2112.00	1	0.385488E	00	0.196088E-02	0.382048E	03	0.0	0.0	0.211988E 00
18	3	3136.00	2176.00	1	0.385678E	00	0.309378E-02	0.379148E	03	0.0	0.0	0.217778E 00
18	4	3136.00	2240.00	1	0.385928E	00	0.364828E-02	0.376478E	03	0.0	0.0	0.226378E 00
18	5	3136.00	2304.00	1	0.386398E	00	0.446708E-02	0.374048E	03	0.0	0.0	0.229988E 00
18	6	3136.00	2368.00	1	0.386778E	00	0.483198E-02	0.372358E	03	0.0	0.0	0.236088E 00
18	7	3136.00	2432.00	1	0.387338E	00	0.537038E-02	0.371488E	03	0.0	0.0	0.244388E 00
18	8	3136.00	2496.00	1	0.388018E	00	0.584708E-02	0.372048E	03	0.0	0.0	0.252938E 00
18	9	3136.00	2560.00	1	0.388838E	00	0.139028E-02	0.373718E	03	0.0	0.0	0.261728E 00
18	10	3136.00	2624.00	1	0.390778E	00	0.911718E-03	0.375818E	03	0.0	0.0	0.270778E 00
18	11	3136.00	2688.00	1	0.390678E	00	0.385668E-02	0.381278E	03	0.0	0.0	0.277838E 00
18	12	3136.00	2752.00	1	0.390308E	00	0.746158E-02	0.387478E	03	0.0	0.0	0.287388E 00
18	13	3136.00	2816.00	1	0.389438E	00	0.114548E-01	0.395028E	03	0.0	0.0	0.294488E 00
18	14	3136.00	2880.00	1	0.390038E	00	0.164198E-01	0.404048E	03	0.0	0.0	0.301278E 00
18	15	3136.00	2944.00	1	0.390468E	00	0.214408E-01	0.414368E	03	0.0	0.0	0.308388E 00
18	16	3136.00	3008.00	1	0.390878E	00	0.272868E-01	0.426708E	03	0.0	0.0	0.314488E 00
18	17	3136.00	3072.00	1	0.390348E	00	0.332038E-01	0.437858E	03	0.0	0.0	0.319828E 00
18	18	3136.00	3136.00	1	0.392118E	00	0.392978E-01	0.450228E	03	0.0	0.0	0.322758E 00
19	1	3200.00	2048.00	1	0.369118E	00	0.720928E-03	0.497698E	03	0.0	0.0	0.204838E 00
19	2	3200.00	2112.00	1	0.368118E	00	0.211348E-02	0.494578E	03	0.0	0.0	0.210818E 00
19	3	3200.00	2176.00	1	0.370348E	00	0.334048E-02	0.491488E	03	0.0	0.0	0.213138E 00
19	4	3200.00	2240.00	1	0.372058E	00	0.432218E-02	0.488508E	03	0.0	0.0	0.217298E 00
19	5	3200.00	2304.00	1	0.373638E	00	0.483638E-02	0.486418E	03	0.0	0.0	0.224418E 00
19	6	3200.00	2368.00	1	0.375308E	00	0.511188E-02	0.484408E	03	0.0	0.0	0.231698E 00
19	7	3200.00	2432.00	1	0.377098E	00	0.477998E-02	0.483618E	03	0.0	0.0	0.239268E 00
19	8	3200.00	2496.00	1	0.378478E	00	0.388438E-02	0.483818E	03	0.0	0.0	0.248948E 00
19	9	3200.00	2560.00	1	0.382778E	00	0.333468E-02	0.485308E	03	0.0	0.0	0.258798E 00
19	10	3200.00	2624.00	1	0.382148E	00	0.171668E-03	0.488038E	03	0.0	0.0	0.267338E 00
19	11	3200.00	2688.00	1	0.385178E	00	0.265508E-02	0.492308E	03	0.0	0.0	0.277038E 00
19	12	3200.00	2752.00	1	0.386418E	00	0.610738E-02	0.497818E	03	0.0	0.0	0.287118E 00
19	13	3200.00	2816.00	1	0.387308E	00	0.101468E-01	0.504808E	03	0.0	0.0	0.297368E 00
19	14	3200.00	2880.00	1	0.389418E	00	0.147828E-01	0.512958E	03	0.0	0.0	0.306918E 00
19	15	3200.00	2944.00	1	0.391218E	00	0.198758E-01	0.521498E	03	0.0	0.0	0.314708E 00
19	16	3200.00	3008.00	1	0.393188E	00	0.253558E-01	0.533358E	03	0.0	0.0	0.323098E 00
19	17	3200.00	3072.00	1	0.395358E	00	0.311288E-01	0.541038E	03	0.0	0.0	0.330578E 00
19	18	3200.00	3136.00	1	0.397778E	00	0.377528E-01	0.553098E	03	0.0	0.0	0.337408E 00
19	19	3200.00	3200.00	1	0.400298E	00	0.430348E-01	0.564768E	03	0.0	0.0	0.342298E 00
20	1	3264.00	2048.00	1	0.385598E	00	0.765758E-03	0.612618E	03	0.0	0.0	0.198738E 00
20	2	3264.00	2112.00	1	0.385568E	00	0.334638E-02	0.607308E	03	0.0	0.0	0.208188E 00
20	3	3264.00	2176.00	1	0.385598E	00	0.355308E-02	0.604108E	03	0.0	0.0	0.204358E 00
20	4	3264.00	2240.00	1	0.385898E	00	0.463178E-02	0.601188E	03	0.0	0.0	0.210218E 00
20	5	3264.00	2304.00	1	0.386038E	00	0.533928E-02	0.599788E	03	0.0	0.0	0.219898E 00
20	6	3264.00	2368.00	1	0.386428E	00	0.563448E-02	0.596978E	03	0.0	0.0	0.222418E 00
20	7	3264.00	2432.00	1	0.386958E	00	0.561318E-02	0.595148E	03	0.0	0.0	0.231288E 00
20	8	3264.00	2496.00	1	0.387398E	00	0.548118E-02	0.596348E	03	0.0	0.0	0.240728E 00
20	9	3264.00	2560.00	1	0.388068E	00	0.325018E-02	0.597688E	03	0.0	0.0	0.250298E 00
20	10	3264.00	2624.00	1	0.388888E	00	0.133848E-03	0.600318E	03	0.0	0.0	0.261758E 00
20	11	3264.00	2688.00	1	0.389388E	00	0.142478E-02	0.604188E	03	0.0	0.0	0.272718E 00
20	12	3264.00	2752.00	1	0.389118E	00	0.471128E-02	0.609218E	03	0.0	0.0	0.280238E 00
20	13	3264.00	2816.00	1	0.389238E	00	0.853398E-02	0.615398E	03	0.0	0.0	0.290438E 00
20	14	3264.00	2880.00	1	0.390138E	00	0.129978E-01	0.622968E	03	0.0	0.0	0.300668E 00
20	15	3264.00	2944.00	1	0.390628E	00	0.178878E-01	0.631208E	03	0.0	0.0	0.310898E 00
20	16	3264.00	3008.00	1	0.390148E	00	0.231558E-01	0.640138E	03	0.0	0.0	0.320158E 00
20	17	3264.00	3072.00	1	0.390058E	00	0.287178E-01	0.649308E	03	0.0	0.0	0.327188E 00
20	18	3264.00	3136.00	1	0.391298E	00	0.344358E-01	0.658488E	03	0.0	0.0	0.334188E 00
20	19	3264.00	3200.00	1	0.390618E	00	0.402148E-01	0.667368E	03	0.0	0.0	0.339478E 00
20	20	3264.00	3264.00	1	0.390948E	00	0.458078E-01	0.675218E	03	0.0	0.0	0.339138E 00
21	1	3328.00	2048.00	1	0.391778E	00	0.801158E-03	0.728948E	03	0.0	0.0	0.191418E 00
21	2	3328.00	2112.00	1	0.391778E	00	0.233848E-02	0.719678E	03	0.0	0.0	0.194588E 00
21	3	3328.00	2176.00	1	0.391908E	00	0.373468E-02	0.716348E	03	0.0	0.0	0.198008E 00
21	4	3328.00	2240.00	1	0.391618E	00	0.486768E-02	0.713618E	03	0.0	0.0	0.202118E 00
21	5	3328.00	2304.00	1	0.852108E	00	0.556398E-02	0.711118E	03	0.0	0.0	0.206308E 00
21	6	3328.00	2368.00	1	0.852338E	00	0.606548E-02	0.709448E	03	0.0	0.0	0.212408E 00
21	7	3328.00	2432.00	1	0.852628E	00	0.595868E-02	0.708698E	03	0.0	0.0	0.221198E 00
21	8	3328.00	2496.00	1	0.853048E	00	0.531398E-02	0.708948E	03	0.0	0.0	0.230208E 00
21	9	3328.00	2560.00	1	0.853648E	00	0.440748E-02	0.710118E	03	0.0	0.0	0.238778E 00

21	10	3328.00	3624.00	3	0.856432E	00	0.223546E-02	0.712695	03	0.0	0.0	0.281718E 00
21	11	3329.00	3699.30	3	0.855222E	00	-0.240338-03	0.716358	03	0.0	0.0	0.263432E 00
21	12	3329.00	3752.30	3	0.855776E	00	-0.330358-02	0.720058	03	0.0	0.0	0.276998E 00
21	13	3328.00	3815.30	3	0.855770E	00	-0.604288-02	0.726778	03	0.0	0.0	0.298822E 00
21	14	3328.00	3880.30	3	0.855346E	00	-0.111208-01	0.733358	03	0.0	0.0	0.301818E 00
21	15	3328.00	3944.30	3	0.861218E	00	-0.157518-01	0.740758	03	0.0	0.0	0.318418E 00
21	16	3328.00	3998.30	3	0.862466E	00	-0.207558-01	0.748318	03	0.0	0.0	0.327088E 00
21	17	3328.00	4052.30	3	0.866228E	00	-0.260848-01	0.755988	03	0.0	0.0	0.339048E 00
21	18	3329.00	4136.00	3	0.869508E	00	-0.314798-01	0.763528	03	0.0	0.0	0.338228E 00
21	19	3328.00	4209.33	3	0.872128E	00	-0.369728-01	0.771368	03	0.0	0.0	0.363068E 00
21	20	3328.00	4264.30	3	0.875688E	00	-0.429338-01	0.778208	03	0.0	0.0	0.372588E 00
21	21	3328.00	4323.30	3	0.875618E	00	-0.476118-01	0.786508	03	0.0	0.0	0.379158E 00
22	1	3332.00	2343.30	3	0.818688E	00	0.812538-03	0.834108	03	0.0	0.0	0.188688E 00
22	2	3332.00	2412.30	3	0.818698E	00	0.218098-02	0.830718	03	0.0	0.0	0.186048E 00
22	3	3332.00	2476.30	3	0.819028E	00	0.383388-02	0.827518	03	0.0	0.0	0.187798E 00
22	4	3332.00	2549.30	3	0.819068E	00	0.598798-02	0.824748	03	0.0	0.0	0.191168E 00
22	5	3332.00	2603.30	3	0.819118E	00	0.590538-02	0.823498	03	0.0	0.0	0.194888E 00
22	6	3332.00	2668.30	3	0.819248E	00	0.438208-02	0.820948	03	0.0	0.0	0.200208E 00
22	7	3332.00	2727.30	3	0.819778E	00	0.673508-03	0.823498	03	0.0	0.0	0.208828E 00
22	8	3332.00	2802.30	3	0.819858E	00	0.587098-03	0.820808	03	0.0	0.0	0.218028E 00
22	9	3332.00	2866.30	3	0.820008E	00	0.478138-02	0.822198	03	0.0	0.0	0.227788E 00
22	10	3332.00	2924.30	3	0.820638E	00	0.313198-02	0.824628	03	0.0	0.0	0.239018E 00
22	11	3332.00	2987.00	3	0.821418E	00	0.991258-03	0.823018	03	0.0	0.0	0.250498E 00
22	12	3332.00	3052.00	3	0.822308E	00	0.194938-02	0.826508	03	0.0	0.0	0.264098E 00
22	13	3332.00	3097.30	3	0.823158E	00	-0.531238-03	0.833858	03	0.0	0.0	0.268278E 00
22	14	3332.00	3233.30	3	0.824118E	00	-0.321258-02	0.843708	03	0.0	0.0	0.274028E 00
22	15	3332.00	3284.30	3	0.827088E	00	-0.135238-01	0.849948	03	0.0	0.0	0.308358E 00
22	16	3332.00	3331.30	3	0.825248E	00	-0.182948-01	0.855588	03	0.0	0.0	0.325938E 00
22	17	3332.30	3377.30	3	0.831538E	00	-0.231518-01	0.862308	03	0.0	0.0	0.338348E 00
22	18	3332.00	3426.00	3	0.834658E	00	-0.282448-01	0.868648	03	0.0	0.0	0.353708E 00
22	19	3332.00	3507.33	3	0.838428E	00	-0.333708-01	0.873388	03	0.0	0.0	0.346948E 00
22	20	3332.00	3554.00	3	0.842338E	00	-0.384838-01	0.877018	03	0.0	0.0	0.370868E 00
22	21	3332.00	3622.33	3	0.846138E	00	-0.433988-01	0.881348	03	0.0	0.0	0.392098E 00
22	22	3332.00	3692.00	3	0.851108E	00	-0.480158-01	0.887038	03	0.0	0.0	0.398198E 00
23	1	3336.00	2343.30	3	0.787468E	00	0.824038-03	0.842918	03	0.0	0.0	0.178768E 00
23	2	3336.00	2412.30	3	0.787468E	00	0.241088-02	0.839388	03	0.0	0.0	0.177258E 00
23	3	3336.30	2476.30	3	0.787618E	00	0.385058-02	0.835698	03	0.0	0.0	0.178718E 00
23	4	3336.00	2549.30	3	0.787918E	00	0.600518-02	0.834068	03	0.0	0.0	0.181158E 00
23	5	3336.00	2604.30	3	0.787338E	00	0.601208-02	0.832108	03	0.0	0.0	0.183948E 00
23	6	3336.00	2669.00	3	0.787398E	00	0.959148-03	0.830918	03	0.0	0.0	0.187508E 00
23	7	3336.00	2732.30	3	0.787578E	00	0.684098-03	0.830688	03	0.0	0.0	0.194828E 00
23	8	3336.00	2809.30	3	0.787838E	00	0.527148-03	0.831298	03	0.0	0.0	0.202888E 00
23	9	3336.33	2873.30	3	0.787958E	00	0.559598-03	0.833638	03	0.0	0.0	0.212408E 00
23	10	3336.00	2937.30	3	0.787938E	00	0.749368-03	0.833458	03	0.0	0.0	0.224018E 00
23	11	3336.33	2988.30	3	0.788568E	00	0.186038-02	0.838468	03	0.0	0.0	0.240288E 00
23	12	3336.30	3052.30	3	0.789428E	00	-0.699038-01	0.842988	03	0.0	0.0	0.250738E 00
23	13	3336.00	3101.30	3	0.790048E	00	-0.377278-02	0.847958	03	0.0	0.0	0.267338E 00
23	14	3336.30	3233.30	3	0.791458E	00	-0.733578-02	0.853158	03	0.0	0.0	0.288838E 00
23	15	3336.30	3247.33	3	0.793138E	00	-0.112938-01	0.859668	03	0.0	0.0	0.298808E 00
23	16	3336.00	3308.30	3	0.795698E	00	-0.155978-01	0.864108	03	0.0	0.0	0.318128E 00
23	17	3336.00	3377.30	3	0.798528E	00	-0.201398-01	0.869978	03	0.0	0.0	0.338778E 00
23	18	3336.00	3438.30	3	0.801618E	00	-0.248198-01	0.873048	03	0.0	0.0	0.335108E 00
23	19	3336.30	3511.00	3	0.805658E	00	-0.295688-01	0.878188	03	0.0	0.0	0.346818E 00
23	20	3336.00	3564.30	3	0.810618E	00	-0.343528-01	0.877568	03	0.0	0.0	0.381048E 00
23	21	3333.30	3628.30	3	0.817158E	00	-0.387738-01	0.877338	03	0.0	0.0	0.397958E 00
23	22	3330.00	3692.30	3	0.824468E	00	-0.430418-01	0.878778	03	0.0	0.0	0.407238E 00
23	23	3336.00	3751.30	3	0.832378E	00	-0.469708-01	0.882958	03	0.0	0.0	0.416758E 00
24	1	3520.00	2349.30	3	0.757348E	00	0.797278-03	0.104918	04	0.0	0.0	0.167878E 00
24	2	3520.00	2412.00	3	0.757108E	00	0.237278-02	0.104588	04	0.0	0.0	0.168778E 00
24	3	3520.30	2476.30	3	0.757228E	00	0.380718-02	0.103118	04	0.0	0.0	0.169438E 00
24	4	3520.30	2540.30	3	0.757448E	00	0.503188-02	0.104108	04	0.0	0.0	0.171888E 00
24	5	3520.00	2604.30	3	0.756928E	00	0.598158-02	0.103928	04	0.0	0.0	0.173888E 00
24	6	3520.00	2661.30	3	0.756718E	00	0.657288-02	0.103858	04	0.0	0.0	0.177068E 00
24	7	3520.00	2732.30	3	0.756598E	00	0.679978-02	0.103078	04	0.0	0.0	0.180128E 00
24	8	3520.00	3796.30	3	0.755468E	00	0.643648-02	0.103968	04	0.0	0.0	0.180778E 00
24	9	3520.00	3860.30	3	0.755348E	00	0.573148-02	0.104158	04	0.0	0.0	0.180848E 00
24	10	3520.33	2623.30	3	0.756628E	00	0.446708-02	0.104438	04	0.0	0.0	0.180788E 00
24	11	3520.00	2699.30	3	0.757028E	00	0.268188-02	0.104778	04	0.0	0.0	0.181978E 00
24	12	3520.00	2752.00	3	0.757268E	00	0.412058-03	0.105158	04	0.0	0.0	0.183188E 00
24	13	3520.30	2816.00	3	0.758818E	00	-0.235378-02	0.105658	04	0.0	0.0	0.258128E 00
24	14	3520.00	2880.00	3	0.759108E	00	-0.953518-02	0.106118	04	0.0	0.0	0.267138E 00
24	15	3520.00	2944.00	3	0.761438E	00	-0.910978-02	0.106598	04	0.0	0.0	0.287348E 00
24	16	3520.00	3008.00	3	0.763498E	00	-0.129788-01	0.107038	04	0.0	0.0	0.305188E 00
24	17	3520.00	3072.00	3	0.764908E	00	-0.170718-01	0.107408	04	0.0	0.0	0.320688E 00
24	18	3520.00	3136.00	3	0.769[2E	00	-0.213098-01	0.107678	04	0.0	0.0	0.343588E 00
24	19	3520.00	3200.00	3	0.772[4E	00	-0.255788-01	0.107778	04	0.0	0.0	0.360848E 00
24	20	3520.00	3264.00	3	0.776[1E	00	-0.298048-01	0.107758	04	0.0	0.0	0.380848E 00
24	21	3520.00	3328.00	3	0.781208	00	-0.338718-01	0.107488	04	0.0	0.0	0.398758E 00
24	22	3520.00	3392.00	3	0.786218	00	-0.377208-01	0.107028	04	0.0	0.0	0.418408E 00
24	23	3520.00	3456.00	3	0.791518	00	-0.412048-01	0.106288	04	0.0	0.0	0.424088E 00

Table D-2 (5 of 7)

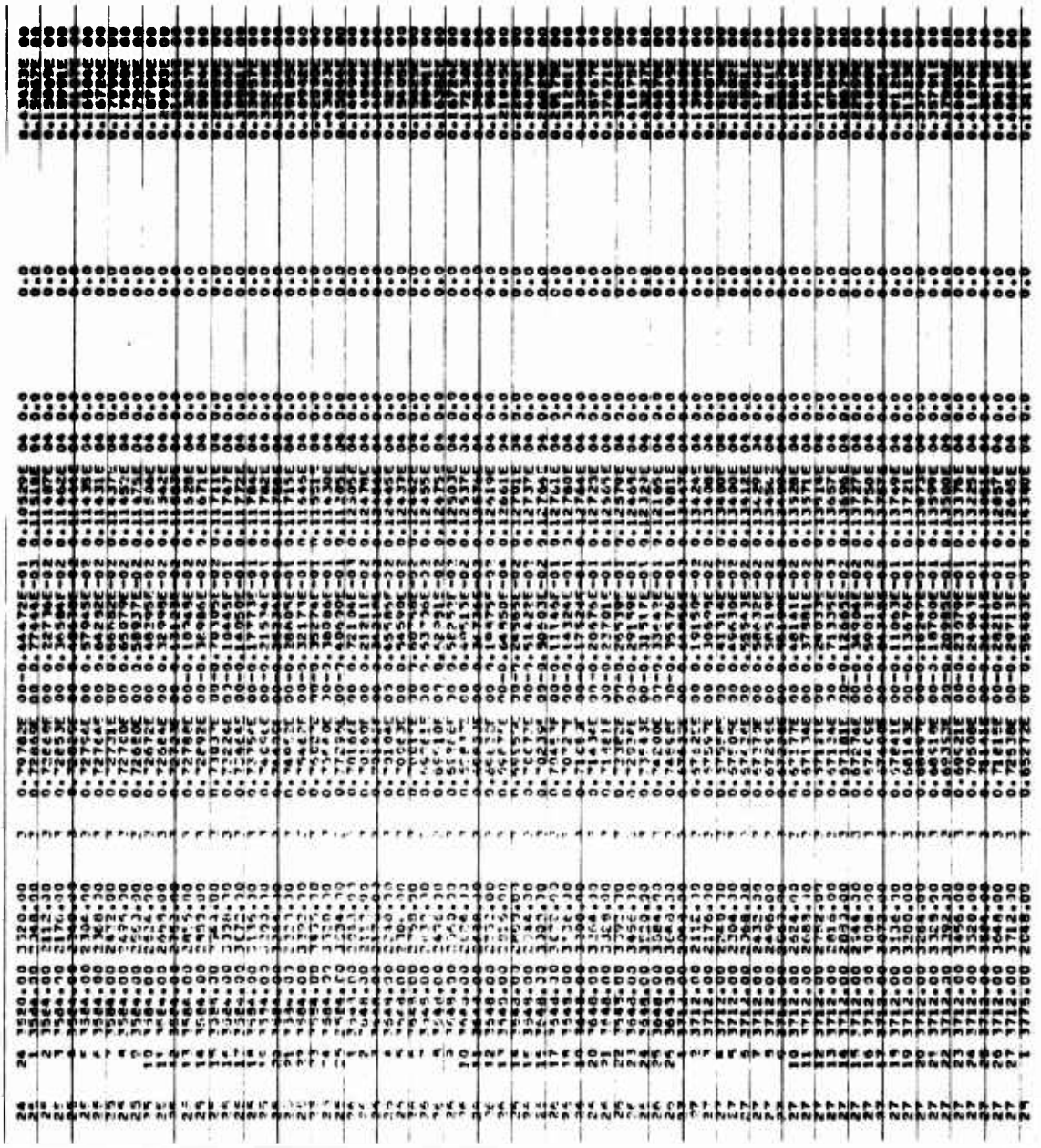

Table D-2 (6 of 7)

	2	3776.00	2112.30		0.65262E 00	0.16557E-02	0.14321E 04	0.0	0.0	0.0	0.13037E 00
	3	3776.00	2176.00		0.65234E 00	0.26780E-02	0.14321E 04	0.0	0.0	0.0	0.13084E 00
	4	3776.00	2240.30		0.65161E 00	0.35820E-02	0.14308E 04	0.0	0.0	0.0	0.13088E 00
	5	3776.00	2304.30		0.65111E 00	0.43145E-02	0.14317E 04	0.0	0.0	0.0	0.13104E 00
	6	3776.00	2368.00		0.65040E 00	0.48562E-02	0.14333E 04	0.0	0.0	0.0	0.13129E 00
	7	3776.00	2432.30		0.64995E 00	0.51461E-02	0.14358E 04	0.0	0.0	0.0	0.13099E 00
	8	3776.00	2496.00		0.64966E 00	0.51918E-02	0.14391E 04	0.0	0.0	0.0	0.13116E 00
	9	3776.00	2560.00		0.64873E 00	0.49530E-02	0.14429E 04	0.0	0.0	0.0	0.13138E 00
	10	3776.00	2624.30		0.64701E 00	0.44327E-02	0.14472E 04	0.0	0.0	0.0	0.13147E 00
	11	3776.00	2688.30		0.64634E 00	0.36279E-02	0.14519E 04	0.0	0.0	0.0	0.13139E 00
	12	3776.00	2752.00		0.64559E 00	0.25444E-02	0.14562E 04	0.0	0.0	0.0	0.13135E 00
	13	3776.00	2816.30		0.64539E 00	0.12017E-02	0.14606E 04	0.0	0.0	0.0	0.13123E 00
	14	3776.00	2880.30		0.64460E 00	0.38472E-03	0.14644E 04	0.0	0.0	0.0	0.13148E 00
	15	3776.00	2944.30		0.64666E 00	-0.21171E-02	0.14672E 04	0.0	0.0	0.0	0.13097E 00
	16	3776.00	3008.00		0.64769E 00	-0.40092E-02	0.14690E 04	0.0	0.0	0.0	0.13097E 00
	17	3776.00	3072.30		0.64936E 00	-0.60104E-02	0.14693E 04	0.0	0.0	0.0	0.13079E 00
	18	3776.00	3136.00		0.65131E 00	-0.80604E-02	0.14679E 04	0.0	0.0	0.0	0.13044E 00
	19	3776.00	3200.30		0.65356E 00	-0.10101E-01	0.14643E 04	0.0	0.0	0.0	0.13001E 00
	20	3776.00	3264.30		0.65711E 00	-0.12077E-01	0.14587E 04	0.0	0.0	0.0	0.12948E 00
	21	3776.00	3328.00		0.66095E 00	-0.13950E-01	0.14507E 04	0.0	0.0	0.0	0.12910E 00
	22	3776.00	3392.30		0.66526E 00	-0.15678E-01	0.14403E 04	0.0	0.0	0.0	0.12858E 00
	23	3776.00	3456.30		0.67014E 00	-0.17230E-01	0.14272E 04	0.0	0.0	0.0	0.12827E 00
	24	3776.00	3520.00		0.67555E 00	-0.18627E-01	0.14117E 04	0.0	0.0	0.0	0.12789E 00
	25	3776.00	3584.30		0.68141E 00	-0.19878E-01	0.13940E 04	0.0	0.0	0.0	0.12760E 00
	26	3776.00	3648.30		0.68757E 00	-0.21027E-01	0.13746E 04	0.0	0.0	0.0	0.12735E 00
	27	3776.00	3712.30		0.69439E 00	-0.22179E-01	0.13535E 04	0.0	0.0	0.0	0.12698E 00
	28	3776.00	3776.00		0.70146E 00	-0.23464E-01	0.13317E 04	0.0	0.0	0.0	0.12672E 00
	1	3840.00	2048.30		0.53009E 00	0.45407E-03	0.15180E 04	0.0	0.0	0.0	0.12134E 00
	2	3840.00	2112.30		0.53064E 00	0.13843E-02	0.15146E 04	0.0	0.0	0.0	0.12091E 00
	3	3840.00	2176.30		0.53046E 00	0.21897E-02	0.15161E 04	0.0	0.0	0.0	0.12041E 00
	4	3840.00	2240.30		0.52975E 00	0.29259E-02	0.15163E 04	0.0	0.0	0.0	0.11987E 00
	5	3840.00	2304.30		0.52891E 00	0.33490E-02	0.15179E 04	0.0	0.0	0.0	0.11940E 00
	6	3840.00	2368.00		0.52838E 00	0.39078E-02	0.15201E 04	0.0	0.0	0.0	0.11887E 00
	7	3840.00	2432.30		0.52734E 00	0.42540E-02	0.15232E 04	0.0	0.0	0.0	0.11838E 00
	8	3840.00	2496.00		0.52654E 00	0.43250E-02	0.15269E 04	0.0	0.0	0.0	0.11788E 00
	9	3840.00	2560.00		0.52592E 00	0.41918E-02	0.15314E 04	0.0	0.0	0.0	0.11748E 00
	10	3840.00	2624.30		0.52434E 00	0.38071E-02	0.15359E 04	0.0	0.0	0.0	0.11704E 00
	11	3840.00	2688.30		0.52350E 00	0.32120E-02	0.15407E 04	0.0	0.0	0.0	0.11663E 00
	12	3840.00	2752.30		0.52285E 00	0.24199E-02	0.15455E 04	0.0	0.0	0.0	0.11630E 00
	13	3840.00	2816.00		0.52269E 00	0.14153E-02	0.15497E 04	0.0	0.0	0.0	0.11603E 00
	14	3840.00	2880.00		0.52240E 00	0.25143E-03	0.15533E 04	0.0	0.0	0.0	0.11582E 00
	15	3840.00	2944.30		0.52267E 00	-0.10604E-02	0.15562E 04	0.0	0.0	0.0	0.11563E 00
	16	3840.00	3008.30		0.52344E 00	-0.24642E-02	0.15574E 04	0.0	0.0	0.0	0.11572E 00
	17	3840.00	3072.00		0.52464E 00	-0.39347E-02	0.15574E 04	0.0	0.0	0.0	0.11600E 00
	18	3840.00	3136.00		0.52628E 00	-0.54321E-02	0.15557E 04	0.0	0.0	0.0	0.11645E 00
	19	3840.00	3200.30		0.52847E 00	-0.68969E-02	0.15520E 04	0.0	0.0	0.0	0.11703E 00
	20	3840.00	3264.30		0.53118E 00	-0.83045E-02	0.15462E 04	0.0	0.0	0.0	0.11780E 00
	21	3840.00	3328.30		0.53442E 00	-0.96299E-02	0.15382E 04	0.0	0.0	0.0	0.11878E 00
	22	3840.00	3392.30		0.53816E 00	-0.10803E-01	0.15278E 04	0.0	0.0	0.0	0.11978E 00
	23	3840.00	3456.00		0.54236E 00	-0.11952E-01	0.15152E 04	0.0	0.0	0.0	0.12108E 00
	24	3840.00	3520.30		0.54705E 00	-0.12772E-01	0.15004E 04	0.0	0.0	0.0	0.12258E 00
	25	3840.00	3584.00		0.55218E 00	-0.13573E-01	0.14837E 04	0.0	0.0	0.0	0.12446E 00
	26	3840.00	3648.00		0.55773E 00	-0.14316E-01	0.14651E 04	0.0	0.0	0.0	0.12670E 00
	27	3840.00	3712.30		0.56361E 00	-0.15009E-01	0.14454E 04	0.0	0.0	0.0	0.12917E 00
	28	3840.00	3776.00		0.56997E 00	-0.16037E-01	0.14249E 04	0.0	0.0	0.0	0.13222E 00
	29	3840.00	3840.00		0.57684E 00	-0.17303E-01	0.14036E 04	0.0	0.0	0.0	0.13604E 00
	1	3904.00	2048.30		0.61057E 00	0.34199E-03	0.15761E 04	0.0	0.0	0.0	0.11133E 00
	2	3904.00	2112.00		0.61031E 00	0.10110E-02	0.15695E 04	0.0	0.0	0.0	0.11107E 00
	3	3904.00	2176.30		0.61051E 00	0.14443E-02	0.15751E 04	0.0	0.0	0.0	0.11081E 00
	4	3904.00	2240.30		0.60992E 00	0.22014E-02	0.15761E 04	0.0	0.0	0.0	0.11060E 00
	5	3904.00	2304.30		0.60914E 00	0.26708E-03	0.15801E 04	0.0	0.0	0.0	0.11040E 00
	6	3904.00	2368.30		0.60819E 00	0.30999E-02	0.16011E 04	0.0	0.0	0.0	0.11040E 00
	7	3904.00	2432.00		0.60719E 00	0.32313E-02	0.16044E 04	0.0	0.0	0.0	0.11040E 00
	8	3904.00	2496.00		0.60636E 00	0.33039E-02	0.16088E 04	0.0	0.0	0.0	0.11040E 00
	9	3904.00	2560.00		0.60491E 00	0.32197E-02	0.16133E 04	0.0	0.0	0.0	0.11042E 00
	10	3904.00	2624.00		0.60328E 00	0.29716E-02	0.16180E 04	0.0	0.0	0.0	0.11037E 00
	11	3904.00	2688.30		0.60206E 00	0.25712E-02	0.16231E 04	0.0	0.0	0.0	0.11026E 00
	12	3904.00	2752.00		0.60206E 00	0.20294E-02	0.16277E 04	0.0	0.0	0.0	0.11030E 00
	13	3904.00	2816.00		0.60185E 00	0.13447E-02	0.16320E 04	0.0	0.0	0.0	0.11038E 00
	14	3904.00	2880.30		0.60117E 00	0.54926E-03	0.16354E 04	0.0	0.0	0.0	0.11040E 00
	15	3904.00	2944.00		0.60115E 00	-0.33188E-03	0.16380E 04	0.0	0.0	0.0	0.11040E 00
	16	3904.00	3008.00		0.60194E 00	-0.12017E-02	0.16394E 04	0.0	0.0	0.0	0.11040E 00
	17	3904.00	3072.00		0.60239E 00	-0.22583E-02	0.16392E 04	0.0	0.0	0.0	0.11042E 00
	18	3904.00	3136.00		0.60360E 00	-0.32588E-02	0.16378E 04	0.0	0.0	0.0	0.11038E 00
	19	3904.00	3200.00		0.60523E 00	-0.41988E-02	0.16348E 04	0.0	0.0	0.0	0.11030E 00
	20	3904.00	3264.00		0.60737E 00	-0.50735E-02	0.16306E 04	0.0	0.0	0.0	0.11040E 00
	21	3904.00	3328.00		0.60995E 00	-0.58758E-02	0.16252E 04	0.0	0.0	0.0	0.11040E 00
	22	3904.00	3392.00		0.61294E 00	-0.65726E-02	0.16119E 04	0.0	0.0	0.0	0.11040E 00
	23	3904.00	3456.00		0.61626E 00	-0.71639E-02	0.16010E 04	0.0	0.0	0.0	0.11040E 00
	24	3904.00	3520.00		0.61999E 00	-0.76846E-02	0.15901E 04	0.0	0.0	0.0	0.11040E 00

30	25	3904.00	3584.30	1	0.624059E 00	-0.30527E-02	0.15735E 04	0.0	0.0	0.339008E 00
30	26	3904.00	3648.30	1	0.627408E 00	-0.84304E-02	0.15575E 04	0.0	0.0	0.340308E 00
30	27	3904.00	3712.30	1	0.631313E 00	-0.88616E-02	0.15413E 04	0.0	0.0	0.341812E 00
30	28	3904.00	3776.30	1	0.634908E 00	-0.94337E-02	0.15241E 04	0.0	0.0	0.343208E 00
30	29	3904.00	3840.30	1	0.638398E 00	-0.10038E-01	0.15068E 04	0.0	0.0	0.344708E 00
30	30	3904.00	3904.30	1	0.641903E 00	-0.11707E-01	0.14902E 04	0.0	0.0	0.346308E 00
31	1	3968.00	2048.10	1	0.392287E 00	0.21756F-03	0.16682E 04	0.0	0.0	0.181812E 00
31	2	3968.00	2112.00	1	0.392777E 00	0.65108E-03	0.16679E 04	0.0	0.0	0.181907E 00
31	3	3968.00	2176.00	1	0.393241E 00	0.10721F-02	0.16682E 04	0.0	0.0	0.182036E 00
31	4	3968.00	2240.00	1	0.393688E 00	0.14344E-02	0.16685E 04	0.0	0.0	0.182177E 00
31	5	3968.00	2304.00	1	0.394111E 00	0.17957E-02	0.16718E 04	0.0	0.0	0.182309E 00
31	6	3968.00	2368.00	1	0.394521E 00	0.19685E-02	0.16740E 04	0.0	0.0	0.182436E 00
31	7	3968.00	2432.00	1	0.394915E 00	0.21213E-02	0.16787E 04	0.0	0.0	0.182556E 00
31	8	3968.00	2496.00	1	0.395305E 00	0.21745E-02	0.16829E 04	0.0	0.0	0.182676E 00
31	9	3968.00	2560.00	1	0.395689E 00	0.21363F-02	0.16876E 04	0.0	0.0	0.182812E 00
31	10	3968.00	2624.00	1	0.396078E 00	0.19952E-02	0.16924E 04	0.0	0.0	0.182936E 00
31	11	3968.00	2688.00	1	0.396474E 00	0.17625E-02	0.16971E 04	0.0	0.0	0.183107E 00
31	12	3968.00	2752.00	1	0.396898E 00	0.14344E-02	0.17016E 04	0.0	0.0	0.183281E 00
31	13	3968.00	2816.00	1	0.397317E 00	0.10451F-02	0.17054E 04	0.0	0.0	0.183408E 00
31	14	3968.00	2880.00	1	0.397765E 00	0.56945E-03	0.17089E 04	0.0	0.0	0.183520E 00
31	15	3968.00	2944.00	1	0.398244E 00	0.57230E-04	0.17111E 04	0.0	0.0	0.183648E 00
31	16	3968.00	3008.00	1	0.398752E 00	-0.49965E-03	0.17125E 04	0.0	0.0	0.183776E 00
31	17	3968.00	3072.00	1	0.399254E 00	-0.10298F-02	0.17125E 04	0.0	0.0	0.183892E 00
31	18	3968.00	3136.00	1	0.399737E 00	-0.15717E-02	0.17110E 04	0.0	0.0	0.184009E 00
31	19	3968.00	3200.00	1	0.400182E 00	-0.20751E-02	0.17083E 04	0.0	0.0	0.184119E 00
31	20	3968.00	3264.00	1	0.400623E 00	-0.25177E-02	0.17042E 04	0.0	0.0	0.184232E 00
31	21	3968.00	3328.00	1	0.401077E 00	-0.29029E-02	0.16985E 04	0.0	0.0	0.184348E 00
31	22	3968.00	3392.00	1	0.401547E 00	-0.32043E-02	0.16916E 04	0.0	0.0	0.184478E 00
31	23	3968.00	3456.00	1	0.402038E 00	-0.34046E-02	0.16836E 04	0.0	0.0	0.184616E 00
31	24	3968.00	3520.00	1	0.402548E 00	-0.34743E-02	0.16740E 04	0.0	0.0	0.184764E 00
31	25	3968.00	3584.00	1	0.403078E 00	-0.34771E-02	0.16637E 04	0.0	0.0	0.184925E 00
31	26	3968.00	3648.00	1	0.403625E 00	-0.33781E-02	0.16528E 04	0.0	0.0	0.185098E 00
31	27	3968.00	3712.00	1	0.404182E 00	-0.32043E-02	0.16416E 04	0.0	0.0	0.185284E 00
31	28	3968.00	3776.00	1	0.404723E 00	-0.29061E-02	0.16305E 04	0.0	0.0	0.185484E 00
31	29	3968.00	3840.00	1	0.405242E 00	-0.25177E-02	0.16197E 04	0.0	0.0	0.185698E 00
31	30	3968.00	3904.00	1	0.405745E 00	-0.20866E-02	0.16095E 04	0.0	0.0	0.185926E 00
31	31	3968.00	3968.00	1	0.406236E 00	-0.16046E-02	0.16000E 04	0.0	0.0	0.186168E 00
32	1	4032.00	2048.00	1	0.376859E 00	0.10493E-03	0.17330E 04	0.0	0.0	0.090844E-01
32	2	4032.00	2112.00	1	0.377674E 00	0.30911E-03	0.17330E 04	0.0	0.0	0.091350E-01
32	3	4032.00	2176.00	1	0.378494E 00	0.50747E-03	0.17330E 04	0.0	0.0	0.091879E-01
32	4	4032.00	2240.00	1	0.379329E 00	0.67544E-03	0.17355E 04	0.0	0.0	0.092402E-01
32	5	4032.00	2304.00	1	0.380178E 00	0.82785E-03	0.17379E 04	0.0	0.0	0.092882E-01
32	6	4032.00	2368.00	1	0.381042E 00	0.93102E-03	0.17410E 04	0.0	0.0	0.093461E-01
32	7	4032.00	2432.00	1	0.381934E 00	0.10036E-02	0.17445E 04	0.0	0.0	0.093740E-01
32	8	4032.00	2496.00	1	0.382840E 00	0.10378E-02	0.17485E 04	0.0	0.0	0.093944E-01
32	9	4032.00	2560.00	1	0.383765E 00	0.10183E-02	0.17527E 04	0.0	0.0	0.094031E-01
32	10	4032.00	2624.00	1	0.384705E 00	0.96534E-03	0.17570E 04	0.0	0.0	0.094031E-01
32	11	4032.00	2688.00	1	0.385667E 00	0.86239E-03	0.17611E 04	0.0	0.0	0.093943E-01
32	12	4032.00	2752.00	1	0.386651E 00	0.72373E-03	0.17650E 04	0.0	0.0	0.093831E-01
32	13	4032.00	2816.00	1	0.387648E 00	0.55325E-03	0.17684E 04	0.0	0.0	0.093580E-01
32	14	4032.00	2880.00	1	0.388737E 00	0.36645E-03	0.17712E 04	0.0	0.0	0.093740E-01
32	15	4032.00	2944.00	1	0.389696E 00	0.14514E-03	0.17733E 04	0.0	0.0	0.093449E-01
32	16	4032.00	3008.00	1	0.390681E 00	-0.44731E-04	0.17745E 04	0.0	0.0	0.093000E-01
32	17	4032.00	3072.00	1	0.391689E 00	-0.27935E-03	0.17749E 04	0.0	0.0	0.092824E-01
32	18	4032.00	3136.00	1	0.392716E 00	-0.47478E-03	0.17744E 04	0.0	0.0	0.107180E 00
32	19	4032.00	3200.00	1	0.393763E 00	-0.64939E-03	0.17730E 04	0.0	0.0	0.117928E 00
32	20	4032.00	3264.00	1	0.394828E 00	-0.78571E-03	0.17709E 04	0.0	0.0	0.120428E 00
32	21	4032.00	3328.00	1	0.395907E 00	-0.87731E-03	0.17680E 04	0.0	0.0	0.120816E 00
32	22	4032.00	3392.00	1	0.396995E 00	-0.93073E-03	0.17647E 04	0.0	0.0	0.140866E 00
32	23	4032.00	3456.00	1	0.398089E 00	-0.93450E-03	0.17609E 04	0.0	0.0	0.159042E 00
32	24	4032.00	3520.00	1	0.399181E 00	-0.89630E-03	0.17570E 04	0.0	0.0	0.170178E 00
32	25	4032.00	3584.00	1	0.400271E 00	-0.84574E-03	0.17532E 04	0.0	0.0	0.181406E 00
32	26	4032.00	3648.00	1	0.401355E 00	-0.77820E-03	0.17496E 04	0.0	0.0	0.193606E 00
32	27	4032.00	3712.00	1	0.402435E 00	-0.70525E-03	0.17465E 04	0.0	0.0	0.209722E 00
32	28	4032.00	3776.00	1	0.403509E 00	-0.79336E-03	0.17434E 04	0.0	0.0	0.220706E 00
32	29	4032.00	3840.00	1	0.404588E 00	-0.98407E-03	0.17410E 04	0.0	0.0	0.235403E 00
32	30	4032.00	3904.00	1	0.405687E 00	-0.13804E-02	0.17385E 04	0.0	0.0	0.249182E 00
32	31	4032.00	3968.00	1	0.406825E 00	-0.20866E-02	0.17358E 04	0.0	0.0	0.335408E 00
32	32	4032.00	4032.00	1	0.408033E 00	-0.32424E-02	0.17330E 04	0.0	0.0	0.367008E 00

IEF142I - STEP WAS EXECUTED - COND CODE 0000
IEF285I SYS1.DUMMY KEPT
IEF285I VOL SER NOS= M2DR#1.
IEF285I SYS1.DUMMY KEPT
IEF285I VOL SER NOS= M2DR#1.
IEF285I SYS1.FORTLIB KEPT
IEF285I VOL SER NOS= K3ITL0.
IEF285I SYS2.FORTLIB KEPT

In Tables D-1 and D-2, IX and IY (IP , IE) are the x and y (ξ , η) indices of the table, x_o and y_o (ξ_o , η_o) are the coordinates of the origin of the area of definition for the coefficient set, NTERMS is the number of terms to be evaluated, $a_o \ldots a_5$ are the coefficients, and RESID is the largest residual found in the evaluation of the coefficients (in elements) as illustrated in Figure 3-12.

APPENDIX E - LISTINGS OF TEST AND EVALUATION PROGRAMS

E.1 SUMMARY

This appendix contains listings of FORTRAN programs used for testing and evaluating the transformations in this report and plotter programs used for generating the world maps.

Listing	Figure
Program used for evaluating the coefficients of $f^*(\xi,\eta)$	E-1
Program used for verifying the f* transformations	E-2
Program used for verifying the polar transformation	E-3
Program used for evaluating coefficients of approximation polynomials	E-4
Program used for generating world maps	E-5
Alternative subroutines for E-5 using the polar transformation	E-6

```
C
C     THIS PROGRAM EVALUATES THE COEFFICIENTS OF THE INVERSE
C     TRANSFORMATION F STAR BY FORCING FSTAR TO MAP POINTS
C     TRANSFORMED BY THE DIRECT TRANSFORMATION BACK ONTO THEMSELVES
C
C
C     PROGRAMMER - E. MICHAEL O'NEILL
C                  COMPUTER SCIENCES CORPORATION
C                  8728 COLESVILLE RD. SILVER SPRING, MD.
C
      IMPLICIT REAL*8 (A-H,O-Z)
      EXTERNAL FUNK
      COMMON RSPH,RO,RO2
      COMMON/ERROOO/ NEMAX,NFLAT,IVARY,NEXTRA
      COMMON /RILRO/ DIFF,VAR(20),VMIN(20),VMAX(20),DV(20),
     1               DELMIN(20),ERR(20,20),NV,NT,MAT,MASK(20)
      EQUIVALENCE (GAMMAS,VAR(12)), (AMUS,VAR(13)),
     1            (GAMIS,VAR(14)), (AMUIS,VAR(15)),
     1            (EM,VAR(16)), (CGAM,VAR(17)), (COMG1,VAR(18))
      DATA GAMMA,DELTA,AMU/0.723601254500,0.790486449100,
     1                     1.649454166000/
      RSPH=1.000
      RO=RSPH/DSQRT(3.000)
      RO2=RO*RO
      RO4=RO2*RO2
      GAMMAS=1.000/GAMMA
      AMUIS=1.000/AMU
      GAMIS=1.000/(GAMMA+RO4*DELTA)
      AMUIS=1.000/(AMU+2.000*RO4*DELTA)
      EM=0.500*(AMUIS-AMUS)
      CGAM=GAMIS-GAMMAS
      COMG1=0.500*(3.000-2.000*GAMMAS-AMUIS)
      DO 10 I=1,11
      VAR(I)=0.000
      VMIN(I)=-2.500
      VMAX(I)=2.500
      DV(I)=1.00-1
      DELMIN(I)=0.10-10
   10 MASK(I)=0
      DO 110 I=12,20
      VMIN(I)=-100.000
      VMAX(I)=100.000
      DELMIN(I)=0.10-10
  110 MASK(I)=0
      MASK(1)=0
      MASK(2)=0
      MASK(3)=0
      MASK(4)=0
      MASK(5)=0
      MASK(6)=0
      MASK(7)=1
      MASK(8)=1
      MASK(9)=0
      MASK(10)=0
      MASK(11)=1
      MASK(12)=0
      MASK(13)=0
      MASK(14)=0
      MASK(15)=0
      MASK(16)=0
      MASK(17)=0
      MASK(18)=0
      DV(12)=0.00100*GAMMAS
      DV(13)=0.00100*AMUS
      DV(14)=0.00100*GAMIS
      DV(15)=0.00100*AMUIS
      DV(16)=0.00100*EM
      DV(17)=0.00100*CGAM
      DV(18)=0.00100*COMG1
      NV=18
      NEMAX=2000
      NT=0
      MAT=0
      M=1
      N=4
      CALL STEPIT(FUNK)
      CALL DISPIN
      STOP
      END
```

Figure E-1 (1 of 3)

```
      SUBROUTINE FUNK
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON/BILBO/ DIFF,VAR(20)
      COMMON RSQW,RO,RO2
      XIN=RO/16.000
      YIN=XIN
      DIFF=0.000
      X=0.000
      DO 10 IX=1,17
      Y=0.000
      DO 5 IY=1,IX
      P=FOMAP(X,Y)
      E=FOMAP(Y,X)
      XR=EMAP2(P,E)
      YR=EMAP2(E,P)
      DIFF=DIFF+(X-XR)**4+(Y-YR)**4
    5 Y=Y+YIN
   10 X=X+XIN
      RETURN
      END
      FUNCTION FOMAP(A,R)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON RSQW,RO,RO2
      DATA GAMMA,OMGAM/0.7236012545582D0,0.2763987454418D0/
      DATA DELTA,OMEGA/0.7904866449)20800,-0.1225441478794601/
      DATA C00,C10,C01/-0.2721705360D),-0.5842168430D),0.2171117480D1/
      DATA C11,C20,C02/-0.4416015150[,-0.3457862740D1,0.1473626570D1/
      DATA RO,R1,R2/0.1483129201,0.)1199726001,0.6051538210D1/
      ASQ=A*A
      A3=A*ASQ
      A4=ASQ*ASQ
      RSQ=R*R
      R4=RSQ*RSQ
      RMA=RO2-ASQ
      FOMAP=GAMMA*A+OMGAM/RO2*A3+
     1      A3*RMA*(OMEGA+RMA*(DO+D)*ASQ+D2*A4))+
     2      A*RSQ*RMA*(DELTA+(RO2-RSQ)*
     3      (C00+C10*ASQ+C01*RSQ+C)1*ASQ*RSQ+C20*A4+C02*R4))
      RETURN
       END
```

Figure E-1 (2 of 3)

```
C
C       THIS PROGRAM VERIFIES THE CORRECTNESS OF THE INVERSE
C       TRANSFORMATION BY COMPARING POSITIONS ON A TRANSFORMED AN
C       RETRANSFORMED GRID
C
C       PROGRAMMER - E. MICHAEL O'NEILL
C                    COMPUTER SCIENCES CORPORATION
C                    8728 COLESVILLE RD. SILVER SPRING, MD.
C
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON RSPH,RO,RO2
      RSPH=1.000
      RO=RSPH/DSQRT(3.000)
      RO2=RO*RO
      DMAX=-1.000
      X=0.000
      ISKIP=16
      SKIP=ISKIP
      DO 100 IX=1,2049,ISKIP
      Y=0.000
      DO 50 IY=1,2049,ISKIP
      XX=RO*X/2048.000
      YY=RO*Y/2048.000
      P=FOMAP(XX,YY)
      F=FOMAP(YY,XX)
      XR=(FMAP2(P,F)*2048.000/RO)
      YR=(FMAP2(F,P)*2048.000/RO)
      DX=X-XR
      DY=Y-YR
      D=DSQRT(DX**2+DY**2)
      IF(D.LT.DMAX) GO TO 50
      WRITE(6,10) X,Y,P,F,XR,YR,DX,DY,D
   10 FORMAT(' X,Y,P,F,XR,YR,DX,DY,D ',9D12.5)
      WRITE(),15) XR,YR,D
   15 FORMAT(1X,3E15.8)
      DMAX=D
   50 Y=Y+SKIP
  100 X=X+SKIP
      STOP
      END
      FUNCTION FMAP2(AA,BB)
      IMPLICIT REAL *8 (A-H,O-Z)
      DATA ROOT3/0.1732050800D1/     ,RO/0.577350269D0/
      DATA GAMMAS/0.1374848477320D1/
      DATA EM/0.4846490181000-2/, CGAM/-0.1316167147400D0/
      DATA COMG1/-0.1595962354700D0/
      DATA C00/0.141[8936115200/, C10/0.8097012865250-1/
      DATA C01/-0.2815285355570D0/, C11/0.1538411287670D0/
      DATA C20/-0.178251207466D0/, C02/0.1069594693140D0/
      DATA D0/0.7591962004670-1/,  D1/-0.2177624904490-1/
      DATA OMGMS/-0.3748484773200D0/
      A=AA*ROOT3
      B=BB*ROOT3
      A2=A*A
      A3=A*A2
      A4=A2*A2
      B2=B*B
      B4=B2*B2
      OMA2=1.000-A2
      FMAP2=RO*(A*GAMMAS+A3*OMGMS+A*B2*OMA2*(CGAM+A2*(EM-CGAM)+(1.00-B2)
     *       *(C00+C10*A2+C01*B2+C11*A2*B2+C20*A4+C02*B4))
     *       +A3*OMA2*(COMG1-OMA2*(D0+D1*A2)))
      RETURN
      END
      FUNCTION FOMAP(A,B)
      IMPLICIT REAL*8 (A-H,O-Z)
      DATA RSO/0.3333333333300/
      DATA GAMMA,OMEGA/0.7736012545558200,0.2763987454461800/
      DATA DELTA,OMEGA/0.7904866491208000,-0.1225441478984D0/
      DATA C00,C10,C01/-0.2721705336D0],-0.5584216880D0],0.2174117480D0]/
      DATA C11,C20,C02/-0.4416015150D0],-0.5457867740D0],0.1075426570D0]/
      DATA D0,D1,D2/0.1483312920D1,0.1119972600D1,0.6051538210D0]/
      ASQ=A*A
      A3=A*ASQ
      A4=ASQ*ASQ
      BSQ=B*B
      B4=BSQ*BSQ
      RMA=BSQ-ASQ
      FOMAP=GAMMA*A+OMGAM/RSQ*A3+
     1       A3*RMA*(OMEGA+RMA*(D0+D1*ASQ+D2*A4))+
     2       A*BSQ*RMA*(DELTA+(BSQ-BSQ)*
     3       (C00+C10*ASQ+C01*BSQ+C11*ASQ*BSQ+C20*A4+C02*B4))
      RETURN
       END
```

Figure E-2

```
C
C       THIS PROGRAM VERIFIES THE POLAR FORM OF THE TRANSFORMATION
C
C       PROGRAMMER - E. MICHAEL O'NEILL
C                    8728 COLESVILLE RD. SILVER SPRING, MD.
C                    COMPUTER SCIENCES CORPORATION
C
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION SS(11,11),SP1(11,11),SP2(11,11),RATIO(11,11)
      DIMENSION P1(2), P2(2), P3(2), P4(2)
C
      SPRO(A,B,C,D,E)=A*(B*B*C)/((C*C+D*D+E*E)**.5D0)
C
      RO=1.000/DSQRT(3.000)
      XO=-RO
      YO=XO
      XIN= RO/5.000
      YIN=XIN
      DX=0.1D-6
      DY=DX
C
      Y=YO
      DO 10 J=1,11
      X=XO
      DO 5 I=1,11
      CALL MAP(X,Y,P1(1),P1(2))
      CALL MAP(X+DX,Y,P2(1),P2(2))
      CALL MAP(X+DX,Y+DY,P3(1),P3(2))
      CALL MAP(X,Y+DY,P4(1),P4(2))
      WRITE(6,1000) X,Y,P1,P2,P3,P4
 1000 FORMAT(1X,10D13.6)
      SP1(I,J)=DX*DY
      SP2(I,J)=AREA(P1,P2,P3)+AREA(P1,P4,P3)
      SS(I,J)=SPRO(SP1(I,J),1.000,RO,X,Y)
      RATIO(I,J)=SS(I,J)/SP2(I,J)
      WRITE(6,1001) I,J,SP1(I,J),SP2(I,J),SS(I,J),RATIO(I,J)
 1001 FORMAT(2I5,4D22.14)
C
    5 Y=Y+YIN
   10 X=X+XIN
      STOP
      END
      FUNCTION AREA(P1,P2,P3)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION P1(2), P2(2), P3(2)
      ASQ=(P1(1)-P2(1))**2+(P1(2)-P2(2))**2
      BSQ=(P2(1)-P3(1))**2+(P2(2)-P3(2))**2
      CSQ=(P3(1)-P1(1))**2+(P3(2)-P1(2))**2
      A=DSQRT(ASQ)
      B=DSQRT(BSQ)
      C=DSQRT(CSQ)
      IF(A.GT.B.AND.A.GT.C) GO TO 10
      COSA=-(ASQ-BSQ-CSQ)/(2.000*B*C)
      CB=B*COSA
      H=BSQ-CB**2
      H=DSQRT(H)
      AREA=0.500*C*H
      RETURN
   10 IF(B.GT.C.AND.B.GT.A) GO TO 20
      COSB=-(BSQ-CSQ-ASQ)/(2.000*C*A)
      AB=C*COSB
      H=CSQ-AB**2
      H=DSQRT(H)
      AREA=0.500*A*H
      RETURN
   20 CONTINUE
      COSC=-(CSQ-ASQ-BSQ)/(2.000*A*B)
      BB=A*COSC
      H=ASQ-BB**2
      H=DSQRT(H)
      AREA=0.500*B*H
      RETURN
      END
```

Figure E-3 (1 of 2)

```
      SUBROUTINE MAP(X,Y,XS,YS)
C
C      PROGRAMMER - E. MICHAEL O'NEILL
C                   COMPUTER SCIENCES CORPORATION
C                   8720 COLESVILLE RD. SILVER SPRING, MD.
      IMPLICIT REAL*8 (A-H,O-Z)
      DATA PI/3.1415926535898D0/
      DATA PI2/0.1570796326794900D1/
      DATA PI4/0.7853981633974500D0/
      DATA  R0/0.5773502691896300D0/
      DATA SCALE/0.3819718634205501/
      IF(X.EQ.0.0.AND.Y.EQ.0.0) GO TO 100
      XX=X
      YY=Y
      IXY=0
      IF(DABS(X).GE.DABS(Y)) GO TO 20
      IXY=1
      YY=XX
      XX=Y
   20 CONTINUE
      PHI=DATAN(DSQRT(X*X+Y*Y)/R0)
      THETA=DATAN(DABS(YY)/DABS(XX))
      AMU=DATAN(SCALE*(THETA+DARCOS(DSIN(THETA)*DCOS(PI4))-PI2))
      C=1.0D0/((1.0D0-DCOS(DATAN(1.0D0/DCOS(THETA))))*DCOS(AMU)**2)
      R=R0*DSQRT(C*(1.0D0-DCOS(PHI)))
      IF(IXY.EQ.0) GO TO 30
      XS=DSIGN(R*DSIN(AMU),X)
      YS=DSIGN(R*DCOS(AMU),Y)
      RETURN
   30 CONTINUE
      XS=DSIGN(R*DCOS(AMU),X)
      YS=DSIGN(R*DSIN(AMU),Y)
      RETURN
  100 XS=X
      YS=Y
      RETURN
      END
```

Figure E-3 (2 of 2)

```
C
C       THIS PROGRAM USES THE IBM SSP ROUTINE SIMQ TO SOLVE A SYSTEM
C       OF SIMULTANEOUS EQUATIONS TO OBTAIN COEFFICIENTS FOR THE
C       APPROXIMATE TRANSFORMATION FA
C
C       FUNCTION TMAP MAY BE MODIFIED TO CALL ANY DESIRED TRANSFORMATION
C       E, F STAR, OR THE POLAR TRANSFORMATION SUBROUTINE MAP
C
C       PROGRAMMER - F. MICHAEL ONEILL
C                    COMPUTER SCIENCES CORPORATION
C                    8728 COLESVILLE RD. SILVER SPRING, MD.
C
      DIMENSION AVECT(5)
      DATA NOUT/6/, MPIC/512/
      READ(5,10) NOUT,MPIC,MAXD
   10 FORMAT(3I5)
      DATA TOLER/1.0/
      INTER=2048/MPIC
      DY=MPIC
      DX=DY
      Y=2048.0
      DO 100 IX=1,INTER
      X=2048.0
      DO 50 IY=1,IX
      CALL DEG3(NC,AVECT,X,Y,DX,DY,TOLER,RESID)
      IF(NC.EQ.3.OR.MAXD.LE.3) GO TO 30
      CALL DEG4(NC,AVECT,X,Y,DX,DY,TOLER,RESID)
      IF(NC.EQ.4.OR.MAXD.LE.4) GO TO 30
      CALL DEG5(NC,AVECT,X,Y,DX,DY,TOLER,RESID)
   30 WRITE(NOUT,40) IX,IY,X,Y,NC,AVECT,RESID
   40 FORMAT(1X,2I5,2F8.2,I5,2X,5E12.5,3X,E12.5)
   50 Y=Y+DY
  100 X=X+DX
      STOP
      END
      SUBROUTINE DEG3(NC,AVECT,X,Y,DX,DY,TOLER,RESID)
      DIMENSION AVECT(5), AVECT(25)
      DIMENSION XP(3),YP(3)
      DATA XP/0.0,1.0,0.0/, YP/0.0,0.0,1.0/
      NC=3
      DO 10 I=1,NC
      XX=X+DX*XP(I)
      YY=Y+DY*YP(I)
      AVECT(I)=TMAP(XX,YY)
      AVECT(I   )=XX
      AVECT(I+3 )=YY
      AVECT(I+6 )=1.0
   10 CONTINUE
      CALL SIMQ(AVECT,AVECT,NC,KS)
      IF(KS.EQ.1) NC=-1
      CALL VER3(X,Y,DX,DY,AVECT,TOLER,RESID,KV)
      IF(KV.EQ.1) NC=0
      AVECT(4)=0.0
      AVECT(5)=0.0
      RETURN
      END
      SUBROUTINE VER3(X,Y,DX,DY,AVECT,TOLER,RESID,KV)
      DIMENSION XP(4),YP(4),AVECT(5)
      DATA XP/0.25,0.75,0.75,0.25/, YP/0.25,0.25,0.75,0.75/
      NV=4
      KV=0
      RESID=0.0
      DO 10 I=1,NV
      XX=X+DX*XP(I)
      YY=Y+DY*YP(I)
      XA=XX*AVECT(1)+YY*AVECT(2)+AVECT(3)
      XT=TMAP(XX,YY)
      RESIT=ABS(XA-XT)
      IF(RESIT.GT.RESID) RESID=RESIT
   10 CONTINUE
      IF(RESID.GT.TOLER) KV=1
      RETURN
      END
```

Figure E-4 (1 of 3)

```
      SUBROUTINE DEG4(NC,AVECT,X,Y,DX,DY,TOLER,RESID)
      DIMENSION AVECT(5), AVECT(25)
      DIMENSION XP(4),YP(4)
      DATA XP/0.0,1.0,1.0,0.0/, YP/0.0,0.0,1.0,1.0/
      NC=4
      DO 10 I=1,NC
      XX=X+DX*XP(I)
      YY=Y+DY*YP(I)
      AVECT(I)=TMAP(XX,YY)
      AVECT(I    )=XX*YY
      AVECT(I+4  )=XX
      AVECT(I+8  )=YY
      AVECT(I+12)=1.0
   10 CONTINUE
      CALL SIMQ(AVECT,AVECT,NC,KS)
      IF(KS.EQ.1) NC=-1
      CALL VER4(X,Y,DX,DY,AVECT,TOLER,RESID,KV)
      IF(KV.EQ.1) NC=0
      AVECT(4)=0.0
      RETURN
      END
      SUBROUTINE VER4(X,Y,DX,DY,AVECT,TOLER,RESID,KV)
      DIMENSION XP(4),YP(4),AVECT(5)
      DATA XP/0.25,0.75,0.75,0.25/, YP/0.25,0.25,0.75,0.75/
      NV=4
      KV=0
      RESID=0.0
      DO 10 I=1,NV
      XX=X+DX*XP(I)
      YY=Y+DY*YP(I)
      XA=XX*YY*AVECT(1)+XX*AVECT(2)+YY*AVECT(3)+AVECT(4)
      XT=TMAP(XX,YY)
      RESIT=ABS(XA-XT)
      IF(RESIT.GT.RESID) RESID=RESIT
   10 CONTINUE
      IF(RESID.GT.TOLER) KV=1
      RETURN
      END
      SUBROUTINE DEG5(NC,AVECT,X,Y,DX,DY,TOLER,RESID)
      DIMENSION AVECT(5), AVECT(25)
      DIMENSION XP(5),YP(5)
      DATA XP/0.0,1.0,1.0,0.0,0.5/, YP/0.0,0.0,1.0,1.0,0.5/
      NC=5
      DO 10 I=1,NC
      XX=X+DX*XP(I)
      YY=Y+DY*YP(I)
      AVECT(I)=TMAP(XX,YY)
      AVECT(I    )=XX*XX
      AVECT(I+5  )=YY*YY
      AVECT(I+10)=XX
      AVECT(I+15)=YY
      AVECT(I+20)=1.0
   10 CONTINUE
      CALL SIMQ(AVECT,AVECT,NC,KS)
      IF(KS.EQ.1) NC=-1
      CALL VER5(X,Y,DX,DY,AVECT,TOLER,RESID,KV)
      IF(KV.EQ.1) NC=0
      RETURN
      END
      SUBROUTINE VER5(X,Y,DX,DY,AVECT,TOLER,RESID,KV)
      DIMENSION XP(4),YP(4),AVECT(5)
      DATA XP/0.25,0.75,0.75,0.25/, YP/0.25,0.25,0.75,0.75/
      NV=4
      KV=0
      RESID=0.0
      DO 10 I=1,NV
      XX=X+DX*XP(I)
      YY=Y+DY*YP(I)
      XA=YY*XX*AVECT(1)+YY*YY*AVECT(2)+XX*AVECT(3)+YY*AVECT(4)+AVECT(5)
      XT=TMAP(XX,YY)
      RESIT=ABS(XA-XT)
      IF(RESIT.GT.RESID) RESID=RESIT
   10 CONTINUE
      IF(RESID.GT.TOLER) KV=1
      RETURN
      END
```

Figure E-4 (2 of 3)

```
      FUNCTION TMAP(A,B)
      REAL*8 EMAP, P, E
      P=(A-2048.0)*0.577350/2048.0
      E=(B-2048.0)*0.577350/2048.0
      TMAP=EMAP(P,E)
      TMAP=TMAP*2048.0/0.577350+2048.0
      RETURN
      END
      FUNCTION EMAP(A,B)
C  THIS IS EQMAP VI
      IMPLICIT REAL*8 (A-H,O-Z)
      DATA RSQ/0.333333333333300/
      DATA GAMMA,OMGAM/0.723601254558200,0.276398745441800/
      DATA DELTA,OMEGA/0.790484449120800,-0.122544148780400/
      DATA C00,C10,C01/-0.272170536001,-0.558421683001,0.217111748001/
      DATA C11,C20,C02/-0.641601515001,-0.345788274001,0.197362457001/
      DATA D0,D1,D2/0.148331292001,0.111997260001,0.604153821001/
      ASQ=A*A
      A3=A*ASQ
      A4=ASQ*ASQ
      RSQ=B*B
      R4=RSQ*RSQ
      RMA=RSQ-ASQ
      EMAP=GAMMA*A+OMGAM/RSQ*A3+
     1       A3*RMA*(OMEGA+RMA*(D0+D1*ASQ+D2*A4))+
     2       A*RSQ*RMA*(DELTA+(RSQ-RSQ)*
     3       (C00+C10*ASQ+C01*RSQ+C11*ASQ*RSQ+C20*A4+C02*R4))
      RETURN
      END
```

Figure E-4 (3 of 3)

```
C
C     THIS PROGRAM PRODUCES WORLD MAPS IN DATA BASE COORDINATES
C     USING THE WOLFPLOT PACKAGE AND CONTINENTAL OUTLINE DATASET
C
C     PROGRAMMER - E. MICHAEL O'NEILL
C                  COMPUTER SCIENCES CORPORATION
C                  8728 COLESVILLE RD. SILVER SPRING, MD.
C
      DIMENSION THETA(3)
      CALL CALSIZ(10.0)
      CALL PLOTST(2001,4)
      CALL SETGRD(0.0,0.0,16.0,10.0,4)
      CALL SCALE(-1.0,14.0,-0.4, 9.5,0)
    1 READ(5,5,END=999) THETA
    5 FORMAT(3F10.3)
      WRITE(6,10) THETA
   10 FORMAT(' ROTATION ANGLES (ORDERED 3 2 1) ',3F12.2)
      DO 15 I=1,3
   15 THETA(I)=THETA(I)/57.3
      CALL WORLD(THETA)
      CALL ERMADV
      GO TO 1
  999 CONTINUE
      STOP
      END
      SUBROUTINE WORLD(THETA)
      INTEGER*2 IX,IY
      DIMENSION COORD(3)
      DIMENSION THETA(3)
      DIMENSION IX(48),IY(48),X(48),Y(48),PP(48),EE(48),IFACE(48)
      DIMENSION XO(6), YO(6)
      DIMENSION XL(12), YL(12)
      DATA XL/0.0, 8.0, 8.0,0.0,0.0,0.0,2.0,2.0,4.0,4.0,2.0,6.0,6.0/
      DATA YL/2.0,2.0,4.0,4.0,2.0,0.0,0.0,6.0,6.0,0.0,0.0,2.0,4.0/
      DATA XO/3.0,7.0,5.0,1.0,3.0,3.0/
      DATA YO/3.0,3.0,3.0,3.0,5.0,1.0/
      DATA PP,EE /96*0.0/
      READ(1) FACTOR
      FACTOR=FACTOR/57.295
      CALL PLOT(XL(1),YL(1),5,' ')
      CALL PLOT(XL(6),YL(6),5,' ')
      CALL PLOT(XL(11),YL(11),2,' ')
    1 LFACE=0
      I=1
      READ(1,END=999) N,    (IY(J),IX(J),J=1,N)
      DO 10 J=1,N
      A=IX(J)*FACTOR
      B=IY(J)*FACTOR
      COORD(1)=COS(B)*COS(A)
      COORD(2)=COS(B)*SIN(A)
      COORD(3)=SIN(B)
      CALL ROT(COORD,THETA)
      CALL QTRAN(COORD,PP(J),EE(J),IFACE)
      IF(IFACE.EQ.LFACE) GO TO 5
      LFACE=IFACE
      IF(J.EQ.1) GO TO 5
      NN=J-I
      CALL PLOT(PP(I),EE(I),NN,' ')
      I=J
    5 PP(J)=PP(J)        +XO(IFACE)
   10 EE(J)=EE(J)        +YO(IFACE)
      NN=N-I+1
      CALL PLOT(PP(I),EE(I),NN,' ')
  101 GO TO 1
  999 CONTINUE
      REWIND 1
      RETURN
      END
```

Figure E-5 (1 of 2)

```
      SUBROUTINE ROT(COORD,THETA)
C       THIS SUBROUTINE ROTATES ONE DATUM POINT ABOUT THREE AXES
      DIMENSION COORD(3), THETA(3), JAX(3,3)
      DATA JAX/3,1,2,2,1,3,1,2,3/
      DO 20 IAXIS=1,3
      X=COORD(JAX(2,IAXIS))
      IF(X.EQ.0.0) X=1.0E-6
      Y=COORD(JAX(3,IAXIS))
      IF(Y.EQ.0.0) Y=1.0E-6
      PHI=ATAN2(Y,X)
      PHI=PHI+THETA(IAXIS)
      R=SQRT(X*X+Y*Y)
      COORD(JAX(2,IAXIS))=R*COS(PHI)
      COORD(JAX(3,IAXIS))=R*SIN(PHI)
   20 CONTINUE
      RETURN
      END
      SUBROUTINE OTRAN(COORD,X,Y,IFACE)
C       THIS SUBROUTINE TAKES AS INPUT THE CARTESIAN COORDINATE ARRAY
C       (COORD) AND RETURNS DATA BASE COORDINATES (X AND Y) AND THE
C       FACE NUMBER (IFACE) OF THE X,Y SYSTEM
C
C       PROGRAMMER - E. MICHAEL O'NEILL
C                    COMPUTER SCIENCES CORPORATION
C                    8728 COLESVILLE RD. SILVER SPRING, MD.
C
      COMMON /TRACOM/ RS,R0,RS0,R4,GAMMA,OMGAM,DELTA,OMEGA,
     1                C00,C10,C01,C11,C20,C02,D0,D1,D2
      DIMENSION COORD(3), C(3), ROT(3,6), IROT(3,6)
      DATA ROT/1.0,1.0,1.0, -1.0,1.0,-1.0, -1.0,1.0,1.0,
     1         1.0,1.0,-1.0, 1.0,-1.0,1.0, 1.0,1.0,-1.0/
      DATA IROT /2,3,1,2,3,1,1,3,2,1,3,2,2,1,3,2,1,3/
C       DETERMINE FACE NUMBER BY FINDING LARGEST (ABS) COMPONENT
      CMAX=ABS(COORD(1))
      J=1
      DO 10 I=2,3
      IF(CMAX.LT.(ABS(COORD(I)))) J=I
      CMAX=ABS(COORD(J))
   10 CONTINUE
      IFACE=J*2
      IF(COORD(J).GE.0.0) IFACE=IFACE-1
C       INTERCHANGE CARTESIAN COMPONENTS TO GET TO FACE SYSTEM
      DO 20 I=1,3
   20 C(I)=COORD(IROT(I,IFACE))*ROT(I,IFACE)
C       PROJECT TO PSI, ETA SYSTEM
      PR=R0/C(3)
      P=C(1)*PR
      E=C(2)*PR
C       TRANSFORM TO X,Y
      X=EMAP(P,E)/R0
      Y=EMAP(E,P)/R0
      RETURN
      END
      FUNCTION EMAP (AA,BB)
C   THIS IS FUNCTION EMAP2
C     PROGRAMMER - E. MICHAEL O'NEILL
C                  COMPUTER SCIENCES CORPORATION
C                  8728 COLESVILLE RD. SILVER SPRING, MD.
C
      IMPLICIT REAL *8 (A-H,O-Z)
      DATA ROOT3/0.17320508001/      ,R0/0.57735026900/
      DATA GAMMAS/0.13748484773201/
      DATA EM/0.4869491981000-2/, CGAM/-0.1316167474000/
      DATA COMG1/-0.1595962354700/
      DATA C00/0.1411896311520D/, C10/0.8097012865280-1/
      DATA C01/-0.2815285355700/, C11/0.1538411287670D/
      DATA C20/-0.1782512074660D/, C02/0.1066594693140D/
      DATA D0/0.7591962004670-1/,  D1/-0.2177624906990-1/
      DATA OMGMS/-0.3748484773200/
      A=AA*ROOT3
      B=BB*ROOT3
      A2=A*A
      A3=A*A2
      A4=A2*A2
      B2=B*B
      B4=B2*B2
      OMA2=1.000-A2
      EMAP2=R0*(A*GAMMAS+A3*OMGMS+A*B2*OMA2*(CGAM+A2*(EM-CGAM)+(1.00-B2)
     *       *(C00+C10*A2+C01*B2+C11*A2*B2+C20*A4+C02*B4))
     *       +A3*OMA2*(COMG1-OMA2*(D0+D1*A2)))
      RETURN
      END
```

Figure E-5 (2 of 2)

```
      SUBROUTINE QTRAN(COORD,X,Y,IFACE)
C
C      THIS SUBROUTINE TAKES AS INPUT THE CARTESIAN COORDINATE ARRAY
C      (COORD) AND RETURNS DATA BASE COORDINATES (X AND Y) AND THE
C      FACE NUMBER (IFACE) OF THE X,Y SYSTEM
C
C      MODIFIED TO USE POLAR FORM OF TRANSFORMATION
C
C      PROGRAMMER - E. MICHAEL O'NEILL
C                   COMPUTER SCIENCES CORPORATION
C                   8728 COLESVILLE RD. SILVER SPRING, MD.
C
      REAL*8 P,E,U,V
      DIMENSION COORD(3), C(3), ROT(3,6), IROT(3,6)
      DATA ROT/1.0,1.0,1.0, -1.0,1.0,-1.0, -1.0,1.0,1.0,
     1         1.0,1.0,-1.0, 1.0,-1.0,1.0, 1.0,1.0,-1.0/
      DATA IROT /2,3,1,2,3,1,1,3,2,1,3,2,2,1,3,2,1,3/
      DATA R0/0.57735026918963D00/
C     DETERMINE FACE NUMBER BY FINDING LARGEST (ABS) COMPONENT
      CMAX=ABS(COORD(1))
      J=1
      DO 10 I=2,3
      IF(CMAX.LT.(ABS(COORD(I)))) J=I
      CMAX=ABS(COORD(J))
   10 CONTINUE
      IFACE=J*2
      IF(COORD(J).GE.0.0) IFACE=IFACE-1
C      INTERCHANGE CARTESIAN COMPONENTS TO GET TO FACE SYSTEM
      DO 20 I=1,3
   20 C(I)=COORD(IROT(I,IFACE))*ROT(I,IFACE)
C      PROJECT TO PSI, ETA SYSTEM
      PRJ=R0/C(3)
      P=C(1)*PRJ
      E=C(2)*PRJ
C      TRANSFORM TO X,Y
      CALL MAP(P,E,U,V)
      X=U/R0
      Y=V/R0
C
      RETURN
      END
      SUBROUTINE MAP(X,Y,XS,YS)
C
C      THIS SUBROUTINE PERFORMS THE POLAR FORM OF THE TRANSFORMATION
C      E STAR
C
C      PROGRAMMER - E. MICHAEL O'NEILL
C                   COMPUTER SCIENCES CORPORATION
C                   8728 COLESVILLE RD. SILVER SPRING, MD.
C
      IMPLICIT REAL*8 (A-H,O-Z)
      DATA PI/3.1415926535898D00/
      DATA PI2/0.1570796326794900D01/
      DATA PI4/0.7853981633974500D00/
      DATA  R0/0.5773502691896300D00/
      DATA SCALE/0.3819718634205500D01/
      IF(X.EQ.0.0.AND.Y.EQ.0.0) GO TO 100
      XX=X
      YY=Y
      IXY=0
      IF(DABS(X).GE.DABS(Y)) GO TO 20
      IXY=1
      YY=XX
      XX=Y
   20 CONTINUE
      PHI=DATAN(DSQRT(X*X+Y*Y)/R0)
      THETA=DATAN(DABS(YY)/DABS(XX))
      AMU=DATAN(SCALE*(THETA+DARCOS(DSIN(THETA)*DCOS(PI4))-PI2))
      C=1.000/((1.000-DCOS(DATAN(1.000/DCOS(THETA))))*DCOS(AMU)**2)
      R=R0*DSQRT(C*(1.000-DCOS(PHI)))
      IF(IXY.EQ.0) GO TO 30
      YS=DSIGN(R*DSIN(AMU),X)
      XS=DSIGN(R*DCOS(AMU),Y)
      RETURN
   30 CONTINUE
      XS=DSIGN(R*DCOS(AMU),X)
      YS=DSIGN(R*DSIN(AMU),Y)
      RETURN
  100 XS=X
      YS=Y
      RETURN
      END
```

Figure E-6

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